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1911

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CONTENTS

1911

No. 1. JANUARY

J. Parsons Schaeffer. Dissectible blotting paper models. Five figures.. 1
B. F. Kingsbury. The term "chromaffin system" and the nature of the "chromaffin reaction"..... 11
Fred. W. Thyng. The anatomy of a 7.8 mm. pig embryo. Three figures... 17

No. 2. FEBRUARY

Helmina Jeidell. A note on the source and character of the early blood vessels of the kidney. Three figures..... 47
Abram T. Kerr. A complete double ureter in man. Ten figures..... 56
George A. Piersol. A self-made naturalist (Professor Joseph Leidy)..... 71
Proceedings of the American Association of Anatomists, Twenty-sixth Session, Brussels, Belgium, August 7 to 11, 1910..... 87
——Twenty-seventh Session, Ithaca, New York, December 28, 29, 30, 1910... 90

No. 3. MARCH

William Snow Miller. The distribution of lymphoid tissue in the lung. Thirteen figures..... 99
Wesley M. Baldwin. Duodenal diverticula in man. Twenty-six figures.... 121
T. D. Merrigan. An unusually large peritoneal fossa. One figure..... 141
Pierre A. Fish. Black tops for laboratory tables..... 145

No. 4. APRIL

William Snow Miller. Abraham Chovet: An early teacher of anatomy in Philadelphia. Seven figures. Two plates..... 147
Frank A. Stromsten. On the relations between the mesenchymal spaces and the development of the posterior lymph hearts of turtles. Three figures..... 173
Samuel T. Orton. Note on an anomaly of the postcentral sulcus simulating the double Rolandic of Giacomini. One figure..... 179

A. Brachet. On the development of the two first blastomeres of the frog's egg 183
G. Carl Huber. A method for isolating the renal tubules of mammalia. One figure 187

BOOK REVIEWS

F. R. Lillie. Normentafeln zur Entwicklungsgeschichte der Wirbeltiere. Herausgegeben von Prof. Dr. F. Keibel. Elftes Heft 186
Normal plates of the development of Necturus maculosus. By Albert C. Eycleshymer and James W. Wilson. Jena, Gustav Fischer. 1910. 50 pp., 3 plates 186
Florence R. Sabin. Gehirn und Rückenmark. Leitfaden für das Studium der Morphologie und des Faserverlaufs. Von Dr. Med. Emil Villiger. Zweite Auflage. Leipzig. Verlag von W. Engelmann. 1910. 278 pages and 224 figures. Price $4.00 195

No. 5. MAY

W. M. Baldwin. The pancreatic ducts in man, together with a study of the microscopical structure of the minor duodenal papilla. Twelve figures 197
Herbert N. T. Nichols. The occurrence in man of double ganglia upon the dorsal roots of the spinal nerves. Five figures 229
Jeremiah S. Ferguson. The reticulum of lymphatic glands. Ten figures .. 249

No. 6. JUNE

Geo. S. Huntington. The development of the lymphatic system in the reptiles 261
Margaret R. Lewis and Warren H. Lewis. The cultivation of tissues from chick embryos in solutions of NaCl, $CaCl_2$, KCl and $NaHCO_3$. Twenty-four figures 277
Charles R. Minot. Note on the blastodermic vesicle of the opossum. Two figures 295
Richard W. Harvey. The volume of the ventricles of the brain. One figure. 301
Jacques Loeb. On the teaching of anatomy 306
Shinkishi Hatai. A formula for determining the total length of the leopard frog (R. pipiens) for a given body weight 309
B. F. Kingsbury. The histological demonstration of lipoids 313
George L. Streeter. Regarding the preservation of anatomical material. Two figures 319
Victor E. Emmel. A dissecting microscope, an accessory of the compound microscope. One figure 323

No. 7. JULY

H. E. Jordan. The microscopic anatomy of the epiphysis of the opossum. Eighteen figures 325
M. T. Sudler and W. J. Baumgartner. The gelatine method of preserving anatomical specimens, with especial reference to neurological preparations. Two figures 339
Franklin P. Mall. Report upon the collection of human embryos at The Johns Hopkins University 343
Simon H. Gage. Retirement of Professor Burt Green Wilder 359
International commission on embryological nomenclature. Announcement. 362

BOOK REVIEW

C. J. H. Localisation motrice et kinesthesique. Les noyaux masticateur et mesencephalique du trijumeau chez le lapin. By Eduard Willems. Le Nevraxe, vol. 12, pp. 1–220, 1911 363

No. 8. AUGUST

M. Dresbach. An instance of pancreatic bladder in the cat. One figure 365
Shinkishi Hatai. An interpretation of growth curves from a dynamical standpoint 373
Albert M. Reese. The anatomy of a double cat. Four figures 383
Newton Miller A method for handling chick embryos. Two figures 391
Eliot R. Clark. An examination of the methods used in the study of the development of the lymphatic system. Seven figures 395
Editorial. Reorganization of the Department of Anatomy at Cornell University Medical School, New York City 415

No. 9. SEPTEMBER

Florence R. Sabin. A critical study of the evidence presented in several recent articles on the development of the lymphatic system. Ten figures. 417
James Crawford Watt. The buccal mucous membrane. Six figures 447

No. 10. OCTOBER

H. E. Jordan. A note on the anatomy of the pulmonary arteries of mammals. Two figures 457
Marjorie M. Johnson. A study in surface anatomy with special reference to the position of the umbilicus. One figure 461
E. Lindon Mellus. A contribution to the study of the cerebral cortex in man. Eight figures 473
Ralph Edward Sheldon. Some new laboratory furnishings. Four plates .. 483

No. 11. NOVEMBER

M. W. Blackman. The anal glands of Mephitis mephitica. Ten figures.... 497
H. E. Jordan. The structure of the heart muscles of the humming bird with special reference to the intercalated discs. Fifteen figures..... 523
John Warren. Biography: Thomas Dwight. Portrait..... 537
Twenty-eighth session of the American Association of Anatomists. Announcement..... 546

BOOK REVIEW

C. J. H. An anatomical guide to experimental researches on the rabbit's brain. By Dr. C. Winkler and Dr. Ada Potter. Amsterdam: W. Versluys. 1911..... 546

No. 12. DECEMBER

Jeremiah S. Ferguson. On the stroma of the prostate gland, with special reference to its connective tissue fibers. Five figures..... 541
George M. Smith. A statistical review of the variations in the anatomic positions of the caecum and the processus vermiformis in the infant..... 549
William A. Hilton. The laryngeal cartilages of Ambystoma. Four figures. 557

BOOK REVIEW

B. D. M. The microscope. Simon Henry Gage. Comstock Publishing Company, Ithaca, New York..... 562
L. F. Barker. Note on M. W. Blackman's article, 'The anal glands of Mephitis mephitica.' 563

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DISSECTIBLE BLOTTING PAPER MODELS

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FIVE FIGURES

Mrs. Gage[1] ('05) was the first to demonstrate the feasibility of using sheets of blotting paper instead of wax plates in the making of models. In a subsequent paper[2] she fully discusses the process employed in this method of reconstruction, and arrives at the following general conclusions:

"The advantages claimed for blotting paper models are the ease and cleanliness of their production and the lightness and durability of the product. The models are broken with difficulty, are easily packed or transported, and when they cleave apart are easily repaired."

My experience in blotting-paper reconstruction leads me fully to confirm the above statements, but it is not the purpose of this report to deal with the above advantages of blotting paper models, nor with the method employed in their construction, since these points have been fully covered by Mrs. Gage in the aforementioned paper. I rather wish briefly to call attention to the practicability of making dissectible models from sheets of blotting paper, and to the ease of their construction.

It is well known that in many cases after a large model is completed many of the parts are so hidden that they are difficult of study; indeed frequently many internal parts cannot be seen at all. Of course this unfortunate state of affairs is obviated if the model is primarily built in segments so that the division planes

[1] The *American Journal of Anatomy*, vol. 5, 1905–06, page xviii.

[2] The method of making models from sheets of blotting paper, *The Anatomical Record* (no. 7) of *The American Journal of Anatomy*, vol. 7, no. 3.

THE ANATOMICAL RECORD, VOL. 5, NO. 1
JANUARY, 1911

fall at appropriate levels. There is no question, however, but that a model may be built with greater ease and accuracy if it can primarily be constructed as a whole. How then may we profit by the advantages of building the model as a whole and yet avoid the disadvantages of having parts hidden from view?

If blotting paper is used as the building material, this may be accomplished in either of two ways: (1) After the building of the model is completed, *i.e.*, the shape accurately determined, the sheets composing the model well fastened together with ribbon- and bank-pins, the external surfaces evened up by scraping with a knife and rubbing with sand paper, and painting the surfaces with hot paraffine, the model may be sectioned in any plane (figs. 3, 4 and 5). This sectioning is best accomplished with a fine stiff-backed saw, with little or no set. The pins that are used to fasten the sheets of blotting paper together are no hindrance to sectioning, as they are readily cut across with the saw. After the sectioning is completed it may be necessary to drive a few pins into the sawed surfaces of the segments in order to refasten the more superficial sheets which may have become loosened by the cutting of pins. This is, however, only necessary when sectioning the model parrallel to the sheets of paper. Sectioning at right angles to the sheets of blotting paper is accomplished with even greater ease than sectioning parallel to them (fig. 5). In order to section at appropriate planes it will be necessary, when building the model, to place some mark on the free surface of the model indicating the positions for the saw cuts later. The individual segments can now be finished, *i.e.*, the portions that were hidden before the sectioning. (2) If when building the model colored sheets of blotting paper are placed at appropriate levels as guide planes, the model when completed may be separated by prying apart with a chisel or other flat instrument at the planes of the colored sheets (fig. 1). The model in this manner may be divided into any number of segments so that all portions of the model may be demonstrated, yet the advantages of building the model as a whole are utilized. Some of the pins used in fastening the sheets of blotting paper together will, of course, protrude after these separations into segments. These

pins may either be cut off or turned over into a clinch. It may be necessary to place some pins in the more superficial layers of paper after the separations are completed. The latter method of making dissectible models is, of course, only applicable when the divisions are to be made along the lines of cleavage of the blotting paper.

In order to facilitate handling and studying the dissected model the segments may be connected up with suitable hinges, and the model thus made to open like the pages of a book (figs. 1, 2 and 4). The hinges may be fastened with screws or with heavy pins or pliable nails. The pins or nails should be of the proper length so that they can be turned over into a clinch, thus securing the hinge and making the model very durable. A strip of canvas or pliable leather might be used instead of a series of hinges. The segments may also be held together by steel pins (fig. 3). The latter is, however, as a rule, not as serviceable as hinging (figs. 1 and 2).

After the segments are thus fastened together the model may be finished as desired. If the surfaces and internal structures were not previously evened and smoothed up with a knife and sand paper this should be done now. The surfaces and internal structures should then be painted over with hot paraffine until a good surface is obtained. If it is deemed desirable to have parts colored differently this may be accomplished by using differently colored paraffines, or Japanese bibulous paper, if dipped in water color or colored inks and applied to the surfaces, also answers the purpose admirably. The paper will, in the wet state, readily mold to any surface. I think that the best results are obtained if the surface is first painted over with a thin layer of paraffine before applying the bibulous paper. Over the bibulous paper a thin layer of paraffine should be applied so as to have a smooth surface. Finally a high gloss may be obtained by rubbing the surfaces with a woolen cloth.

EXPLANATION OF FIGURES

1 Photograph of a dissectible model of the right nasal fossa. The model was primarily built as a whole and then sectioned at appropriate levels by prying apart the model at these planes. Colored sheets of blotting paper were placed at these intervals as guide planes for the segments. Note that the segments are hinged together and that the model opens like the pages of a book. All of the internal structures are thus exposed for study, and any structure may be carried through the reconstruction with ease.

2 This is a lateral view of the same model as that in fig. 1. Note the method of hinging the several segments.

3 Photograph of a dissectible model of the left nasal wall. The model was built as a whole and then sectioned with a fine stiff-backed saw, with little or no set. The cavity of the maxillary sinus was missed and the small door (middle section) was later cut out and the sinus thus exposed. The segments are held together with steel pins. The small door is fastened with an appropriate hinge.

4 Photograph of a dissectible model of portion of the lateral nasal wall. The finished model was divided into two segments with a saw and the parts connected together with a pair of hinges. The hinges are secured with heavy pins which were of the proper length so that they could be turned into a clinch.

5 Photograph of a model of portion of the head of a 35-day human embryo. Note how the structures of the left nasal fossa are exposed for study. This was accomplished by sawing across the fossa. Note that the segment containing the lateral wall of the fossa is connected up with the main model with a pair of hinges.

4

THE TERM "CHROMAFFIN SYSTEM" AND THE NATURE OF THE "CHROMAFFIN REACTION"

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The general use by morphologists of the terms, chromaffin system, chromaffin cells, chromaffin tissue, chromaffin reaction, etc., suggests this critical note as timely.

Kohn ('98) first introduced this term as a name for the cell-groups found by him in the sympathetic system, the medulla of the suprarenal gland, the carotid gland, etc., which assume a brown color when treated with chromic acid or dichromates. Observation of this interesting color reaction is older than Kohn's extensive and systematic study, going back, I believe, to Henle ('65). Stilling ('98) preferred the term "*chromophile*," while Poll ('02) has more recently suggested the term *phaeochrome* (brown color reaction with chrome salts).

The query is but natural, therefore, as to the cause and nature of the chromaffin reaction and the attempt to determine this was precipitated by the peculiar way the medulla of the suprarenal gland behaved in different fixing solutions.

Naturally, the effect of reagents on the medulla of this organ has already received considerable attention. The medulla blackens with osmic acid (Schultze and Rudneff, '65, Bonnamour, '05); turns green to blue with iron chlorid (Vulpian, '56, Fusari, '91, Giacomini, '02, Mulon, '03, Stoerck and Haberer, '08); reduces gold chlorid (Mayer, '72, Loewenthal, '94) stains intravitam with neutral red (Mayer, '96); stains with basic stains (many authors).

Whether or not the reaction is associated with, and if so limited to, granules in the cytoplasm has been a matter of discussion which does not particularly concern us now. Hultgren and Anderson ('99) Grynfeltt ('03) Kohn ('00) Wiesel ('02) Poll and Sommer ('03) find that the reaction takes place in granules; Rabl ('91) Stoerk and Haberer ('08), on the other hand, found the chromaffin reaction to be a diffuse one. It seems to have been shown however,—and this is a more pertinent point,—that after treatment with potassium dichromate or Müller's fluid, the reaction is diffuse, while potassium dichromate and formaldehyde limits it to granules in the cells of the medulla, (Kohn, '04).

Lastly, Neubauer and Langstein ('02) pointed out that adrenalin blackens osmic acid solutions as does the medulla, and Elliott and Tuckett ('06) state that the intensity of the chromaffin reaction corresponds to the amount of adrenalin present.

This brings me to the comparison of the reaction of the "chromaffin cells" of the suprarenal and those of adrenalin. It is a simple matter to test these reactions as I have done by taking free hand sections of the living suprarenal gland and placing them in the reagents in watch glasses, carrying out the corresponding test of adrenalin as is customary in test tubes. The results are arranged in tabular form below:

REAGENT	SECTIONS OF SUPRARENAL (MEDULLA)	SOLUTION OF ADRENALIN 1:1000
Potassium dichromate	Quickly assumes brown color	Precipitate, reddish brown, formed at once
Potassium dichromate in alkaline solution	Quickly assumes brown color	Precipitate, reddish brown, formed at once
Potassium dichromate and formalin	Quickly assumes brown color	Precipitate, reddish brown, formed at once
Potassium dichromate and acetic acid	Assumption of brown color which subsequently fades	Precipitate formed by potassium dichromate, soluble on addition of acetic acid

REAGENT	SECTIONS OF SUPRARENAL (MEDULLA)	SOLUTION OF ADRENALIN 1:1000
Zenker's fluid	Color variable; usually present but disappears on standing	Not tested
Silver nitrate (ammoniacal solution)	Medulla (and zona reticularis) turns a slaty (gray) black	Grayish-black precipitate
Osmium tetroxid (Osmic acid)	Medulla turns immediately black; subsequent blackening of cortex	Black precipitate
Flemming's fluid. (Osmic acid, chromic acid and acetic acid)	Medulla assumes a black color, which subsequently fades more or less completely	Color turns to brownish red and subsequently blackens; no definite precipitate
Gold chlorid	Medulla takes on a brownish red, becoming more of a purple on standing	Turns brownish red with a tinge of purple, which becomes stronger on standing
Ferric chlorid	Medulla a blue-green; turns brown on adding ammonia	Green color, turning brownish red on heating or adding ammonia
Potassium ferricyanide	Brownish red color appears on warming	Green color, turning reddish brown on heating
Fehling's solution	Medulla turns immediately a brick red; cortex a bluish purple	Reduction in the cold (green-yellow-red ppt.)
Benedict's solution (one fluid formula)	Medulla turns gray; intensified on heating	On heating, reduction (whitish-yellow ppt.)

The parallelism shown in the simple if rather crude series of tests, leaves little doubt that the staining reactions of the suprarenal medulla, with osmic acid, chromic acid, ferric chlorid, etc., are due to the adrenalin present although of course there may be other reducing substances present as well. The so-called chromaffin reaction therefore depends not upon any special affinity

of the cells of the suprarenal for chromium salts, but simply and solely is due to a reduction of the chromate to a chromium trioxid (?) combination by strong reducing substances present. The grouping of organs or cell groups based upon the occurrence of reducing reactions has little significance unless it can be shown that the reducing substances are identical. The animal body is rich in reducing substances; most cell bodies show a more or less well marked "chromaffin reaction," due to reduction of chromates. The nervous system shows in the assumption of the well-known brown color when it is "mordanted" in dichromate for the Weigert hematoxlyin method, a "chromaffin reaction" proceeding more slowly, it is true, due in this case to a reduction by the lipoids present. The cortex of the suprarenal, to go no further,—shows, particularly in the zona reticularis, a marked brown color with chromates which has, however, somewhat different reaction conditions. If it is desirable to have the reduction of chromates represented in the name of the "system," *phaeochrome* seems to the writer preferable to chromaffin or chromophile.

The peculiar behavior of the suprarenal in different fixing fluids becomes clear in the light of the chemical reactions of adrenalin.[1] When placed in Flemming's fluid, the medulla rapidly turns black, but on standing, the black coloration disappears, the black being transferred, so to speak (that is, in a suprarenal whose cortex is rich in lipoids as in the dog or cat or guinea pig), to the cortex whose rich lipoid content blackens more slowly, so that after twenty-four hours, the medulla is grayish white, the cortex black. In osmic acid solution alone the blackening of the medulla is persistent, the difference in the Flemming's fluid reaction being due undoubtedly to the solvent action of the acetic acid probably assisted by the presence of the oxidizing chromic acid. In potassium dichromate acetic (Tellyesnizcky's fluid), the brown color of the medulla largely disappears, which is not the case in neutral dichromate solutions or dichromate combined with formalin (a reducing substance) as in Orth's fluid. In tissue fixed in Zen-

[1] Cf. also: Oppenheimer: Handbuch der Biochemie, vol.1, pp.768–9.

ker's fluid the brown color which appears at first gradually fades, the color residue depending apparently on the duration of the fixation. Acid fixing fluids are not adapted for the fixation of the medulla of the suprarenal,—from this side at least. The mixture employed by Harvey ('06) for the fixation of gastric glands (equal parts water, formalin, 3 per cent dichromate and saturated solution of mercuric chlorid), or a formula of similar composition such as Helly's fluid recommended by Poll therefore give excellent results with the medulla.

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THE ANATOMY OF A 7.8 MM. PIG EMBRYO

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THREE FIGURES[2]

Graphic reconstructions of a 12 mm. pig embryo have been published by Dr. F. T. Lewis ('03) and used in Minot's "Laboratory Text-book of Embryology." These reconstructions have been exceedingly helpful to the student in acquiring an understanding of embryology. Therefore it seemed desirable to have similar reconstructions of a still younger stage. At the suggestion of Prof. C. S. Minot I have made a series of reconstructions to show the anatomy of a 7.8 mm. pig embryo.

The drawings were made from transverse sections by the modified graphic reconstruction method of His. The surface modeling has been inferred from a study of the sections with the exception of a few instances when wax models were made to aid in its interpretation.

EXTERNAL FEATURES

In contour this embryo resembles closely the one represented by Keibel ('07) in fig. 15, Taf. II. There are four regions of bending or flexures, the cephalic, the cervical, the dorsal and the sacral. The cephalic is in the region of the mesencephalon and causes the anterior portion of the brain to be bent at an acute angle to the posterior. The cervical occurs in the region of the

[1] This investigation has been aided by a Bullard Fellowship established at Harvard Medical School in the memory of John Ware.

[2] The reconstruction represented in fig. 1 of this paper is used in the second edition of Prof. Minot's "Laboratory Text-book of Embryology." Since this plate was made several minor changes have been made in the drawing.

neck, where the spinal cord joins the brain. It is at an obtuse angle. The dorsal occurs approximately on a level with the middle of the anterior limb bud. It also forms an obtuse angle causing a convexity of the back. The sacral is in the caudal region and is more nearly at a right angle.

Four branchial arches are observed in fig. 3, separated by ectodermal grooves, the branchial clefts. The fourth is seen at the bottom of a pit (*S.cer.*) which represents the developing cervical sinus. In size the branchial arches decrease from anteriorly posteriorly. The maxillary processes of the first arch have united on either side with the lateral nasal and globular processes so that the nasal pits are now shut off from the oral cavity. The nasal fossae are, however, separated by an exceptionally broad median nasal process.

The ectodermal invagination on either side to form the lens of the eye has just closed.

The great development of the heart causes a conspicuous swelling of the ventral body wall directly under the branchial arches.

The umbilical cord is comparatively short and bends to the right. The limb buds are conspicuous structures.

THE ALIMENTARY CANAL AND ITS APPENDAGES

Mouth. The mouth (*M.*) shown in figs. 1 and 2 is wide and slitlike. It is bounded posteriorly by the mandibular processes (*Mdb.*) of the first arch, and anteriorly by the median nasal process united on either side with the maxillary process. In the dorsal wall of the oral cavity there is a distinct longitudinal furrow which leads to the opening of the hypophysis.

Hypophysis. The hypophysis (*Hyp.*) is a flattened diverticulum from the ectoderm of the oral cavity closely applied to the ventral surface of the brain. Its distal end is wider than its proximal part, but does not show any trace of forking. The oral membrane has disappeared except for a small remnant attached immediately posterior to the outlet of the hypophysis.

Pharynx. The pharynx is dorso-ventrally compressed and has its greatest width in the region of the mouth. It gradually

becomes narrower as it extends posteriorly to its bifurcation into the oesophagus (*Oe.*) and trachea (*Tr.*) A little above the point of bifurcation it is bent upon itself at an angle corresponding to the neck-bend of the embryo. A little caudal to the hypophysis in the median line occurs the most anterior of the entodermal structures. It is a small conical diverticulum (Seessel's pocket, *S. P.*) resembling somewhat the hypophysis. Still farther caudal the median wall of the pharynx presents another conspicuous projection (*x*). The development of this structure has been followed by Mrs. Gage ('05), who concludes that it represents the bursa pharyngea identified by Killian ('88). In the anterior ventral wall of the pharynx there is a deep conspicuous groove partially separating the ventral ends of the mandibular processes of the first visceral arch. Immediately posterior to this median oral groove is the small rounded elevation, the tuberculum impar (*T. i.*), which has been said, (His, '85) to form the tip and a large portion of the body of the tongue. Some investigators, (Kallius '01, Hammar '02), however, assert that later in development a more extensive elevation forms from the medial dorsal surface of the mandibular processes, and that it is this which forms the greater portion of the anterior part of the tongue. Posteriorly the tuberculum impar is fused to the converging ventral ends of the descending hyoid arches which form the anterior part of a median elevation slightly higher than that of the tuberculum impar. The original separation of the two is now indicated by a slight V-shaped groove. The apex of this groove marks the place of origin of the median thyroid (*Th. med.*).

The ventral ends of the descending third visceral arches have also converged toward the median line, and have fused with the median elevation of the second arches to form a conspicuous posterior part, the epiglottis (*Epgl.*). The remaining anterior portion of the elevation contributes according to His ('85) to the development of the posterior part or root of the tongue. Behind the epiglottis and at a much lower level, the internal wall of the pharynx presents a slight median groove bounded laterally by the arytenoid ridges which represent the lateral portions of the furcula described by His ('85). This groove leads pos-

teriorly along the ventral wall of the pharynx to the glottis, the slitlike opening of the larynx into the pharynx.

An approximation of the entoderm of the arytenoid folds occurs in the region of the larynx. Thereby two passages for a distance are formed, a broader dorsal channel and a ventral slitlike one, which leads into the trachea. A little more posteriorly, the dorsal passage forks, one channel passing into the oesophagus and the other into the trachea.

Pharyngeal pouches. The pharyngeal pouches are shown in fig. 2. There are four on either side. As described by Hammar ('02) and confirmed by Fox ('08) each possesses a dorsal and a ventral diverticulum. In the 7.8 mm. pig embryo all are in contact with the ectoderm forming closing plates, except the fourth. Anteriorly the pharynx is wide and much compressed dorso-ventrally. From the anterior lateral border the first or auditory pouch (*Ph. P. 1.*) arises. Its dorsal diverticulum is the most conspicuous portion. It is a wing-like projection extending obliquely upward and outward, ending in a pointed process. There is thus formed a prominent ridge extending from the pointed tip of the dorsal process downward, inward and forward to the oral epithelium between the hypophysis and the angle of the mouth. This has been named by Moldenhauer ('77) the sulcus tubo-tympanicus. The contact of this pouch with the ectoderm is made by a lateral ridge extending from the dorsal pointed process posteriorly downward for about three-fourths of its distance. Below the point of contact there is a small ventral diverticulum less developed than the corresponding structure of the other pouches, but causing a distinct ventral ridge on the floor of the pharynx extending inward and backward toward the median line.

The pharynx is also quite wide in the region of the second pouch (*Ph. P. 2.*). Immediately posterior to this it retreats considerably toward the median line. From the lateral and ventral border of this widened portion of the pharynx the second pouch develops. Its dorsal diverticulum somewhat resembles that of the auditory pouch being flat and extending upward and outward. It terminates in two short pointed processes leaving a slight indentation down over which passes the tympanic branch (*N. tymp., fig. 3.*)

of the glossopharyngeal nerve. Between this diverticulum and the one anterior there is a V-shaped notch. The surface of contact to form the closing plate of this pouch is very extensive as shown by Fox ('08). It is formed by a deep plate-like fold of the entoderm jutting out at almost right angles to the axis of the pharynx. The border of contact recedes from the ventral border of the dorsal diverticulum medianly to its extreme lower tip. This fold thus produces a prominent ventral diverticulum extending down between the second and third visceral arches with its extreme tip pointed medianly. Between the ventral tips of the diverticula of the two sides is the median thyroid (*Th. med.*) a small branching mass of entoderm.

The third pouch, likewise, arises from the latero-ventral wall of the pharynx. It is plate-like and nearly parallel with the second. Its dorsal diverticulum is smaller than the two preceding, but its ventral diverticulum, which forms the thymus gland, is more prominent. It is a deep fold from the entoderm. Its upper lateral border is nearly parallel to the corresponding border of the third. Medially they tend to converge. A little more than half of its border reaches the ectoderm. Beyond, the ventral part is free. Immediately behind the third pouch the pharynx recedes abruptly toward the median line.

The fourth pharyngeal pouch (*Ph. P. 4.*) conspicuously smaller than the preceding joins the pharynx a little anterior to its bifurcation into the oesophagus and trachea. It possesses a rounded dorsal diverticulum, attached to the pharynx, somewhat constricted off from a more ventral tubular portion which extends posteriorly and somewhat dorsally. This posterior ventral portion is comparable with the ventral process of the other pouches as emphasized by Fox ('08). From the ventral surface of the fourth pouch a prominent ridge extends across the ventral wall of the pharynx to meet the corresponding one from the other side.

Lungs. Above the cardiac end of the stomach the trachea bifurcates to form two short bronchi, fig. 1. Each entodermal bronchus ends in a symmetrical bilobed enlargement, the lung. The left bronchus has been cut away in the figure. The trachea just above its point of bifurcation shows an indication of the developing eparterial bronchus (not represented in the drawing).

Liver. The liver (*hepar*) is incompletely divided into four lobes. Two lobes, a dorsal and a ventral, appear on either side. In fig. 1 a median sagittal section of the liver is represented. In fig. 2 it is represented as cut more to the right, and here a better idea is obtained of its comparatively large size.

Stomach. The stomach (*St.*) has so revolved on its axis that its dorsal border nearly faces toward the left. Its previous ventral border is now toward the right. Viewed from the left and ventrally it has an oval shape, tapering at either end, while from the left and dorsally it is very much flattened hardly thicker than the oesophagus. Just below the entrance of the oesophagus, the cardiac end presents a small dorsally directed elevation corresponding to the prominent pouch of the stomach of the 12 mm. pig embryo (Lewis '03, fig. 3).

Gall bladder and pancreas. Ventral to the pyloric end of the stomach is the hepatic diverticulum from which project several cords of cells connecting with the liver trabeculae, one of which will eventually form the hepatic duct. The distinct pouch at the distal ventral end of the hepatic diverticulum together with the more constricted intermediate portion represent the gall bladder and the cystic duct. The hepatic diverticulum opens into the right side of the duodenum. In a younger pig embryo (Thyng '08, fig. 1), this opening was on the ventral side. The change has occurred by a revolving of this portion of the intestine, thus causing the hepatic diverticulum to be bent at nearly a right angle.

The ventral pancreas (*Panc. v.*) joins the hepatic diverticulum near its opening into the duodenum. It is an elongated budding mass of entoderm, extending on the right side of the duodenum ventral to the portal vein (*V. p.*). The dorsal pancreas (*Panc. d.*) is larger than the ventral. It joins the duodenum on its dorsal side, posterior to the opening of the hepatic diverticulum. It branches in the mesenchyme of the greater omentum, sending a posterior subdivision to the right and ventrally which overhangs the portal vein. The ventral and dorsal pancreas will later anastomose on the right side of this vein. Neither the dorsal nor the ventral pancreas as yet possesses an open outlet. In the pig the

duct of the dorsal pancreas persists, the ventral becomes obliterated (Stoss '91).

Intestine. From the dorsal pancreas the intestine (*Int.*) extends in the dorsal mesentery into the umbilical cord (*Um. C.*) where it receives the yolk stalk (*Yk. S.*). It then returns to the body and extends posteriorly into the cloaca (*Cl.*). Beyond the cloaca it is continued out into the tip of the tail as the tail gut (post-anal gut). Posterior to the cloaca it is slender except near its termination where its lumen distinctly enlarges. The tail gut very early disappears. It has become obliterated in the 12 mm. pig embryo, (Lewis '03, plate 3).

Cloaca. The cloaca (*Cl.*) represents a dorso-ventrally expanded portion of the intestinal tract from which the allantois (*All.*) extends forward and ventrally into the posterior wall of the umbilical cord. The allantois is a slender tube as it leaves the ventral portion of the cloaca. In the umbilical cord it soon becomes considerably dilated. Lateral to the origin of the allantois the cloaca receives the Wolffian ducts. (*D. W.*). The anterior portion of the cloaca to which the Wolffian ducts and allantois are connected is partly separated from the dorsal intestinal portion by a fold (uro-rectal) to form the urogenital sinus. In the 12 mm. pig embryo, (Lewis '03, plate 3), the cloaca has become more extensively separated into its urogenital and rectal divisions. The ventral wall of the cloaca anastomoses with the adjacent ectoderm to form a median raphe, the cloacal membrane.

URONGENITAL SYSTEM

The large Wolffian ridges or mesonephroi (*Mes.*) are shown in part in fig. 2. They consist mainly of the mesonephric tubules and the associated mesial glomeruli. They begin anteriorly near the anterior border of the liver and extend almost the entire length of the body cavity. The posterior portion of each ridge, however, is occupied only by the large Wolffian duct (*D. W.*) which joins the corresponding antero-lateral portions of the cloaca. The division of the cloaca into which the ducts empty is nearly separated from the dorsal rectal portion as already described. Just before the Wolffian ducts open into the urogenital region of the

cloaca, each presents an evagination (*Met.*) from its dorsal wall, extending into the mesenchyme above. This evagination, the primitive pelvis of the metanephros, shows three lobes developing from its surface, a posterior bud near its union with the Wolffian duct and two terminal ones.

NERVOUS SYSTEM

Brain. The longitudinal axis of the brain and spinal cord share the corresponding flexures already described for the embryo. The ventral flexure of the floor of the metencephalon is already quite apparent. The three primary divisions of the brain, prosencephalon, mesencephalon and rhombencephalon, have undergone the following differentiation in the 7.8 mm. pig embryo.

Prosencephalon. The prosencephalon, (figs. 1 and 3) is partially divided into diencephalon (*Dien.*) and telencephalon (*Telen.*) by a prominent external groove and a corresponding internal ridge, the velum transversum, (Johnson '09). This ridge extends from the dorso-median line around the interior of the prosencephalon ending in front of the optic evagination. The cerebral hemispheres are shallow evaginations from the dorso-lateral surface of the telencephalon, the first neuromere of the brain. A small pit in the ventral wall of each hemisphere indicates the developing olfactory area (rhinencephalon). Ventral to the olfactory depression there is a low broad arch which represents the corpus striatum. Caudal to this there is another ridge or arch which overlies the groove leading from the optic cup. In this ridge the optic fibres later develop, and so Johnson has named it the optic ridge. It is separated from the developing corpus striatum by a groove, the praeoptic recess which crosses the thin lamina terminalis and extends out into the optic stalks.

Diencephalon. The diencephalon is bounded from the mesencephalon (*Mesen.*) by an internal ridge extending transversely across the brain toward the tuberculum posterius. This division is narrow, but considerably dilated dorso-ventrally. A large concavity marks each dorso-lateral wall. In the anterior part of each latero-ventral wall is the optic evagination. In the median

line the brain wall is thickened just behind the tip of the oral hypophysis, to form its nervous portion or posterior lobe. Still farther caudal there is a slight depression, the mammillary recess, causing a corresponding external elevation of the floor of the diencephalon. The number of neuromeres entering into the formation of diencephalon is questionable. Johnson ('08) gives two neuromeres to this section of the brain.

Mesencephalon. The posterior boundary of the mesencephalon (*Mesen.*) is a ridge known as the plica-rhombomesencephalica. Each dorsal zone of this division presents three concavities or neuromeres on its internal surface, and corresponding swellings on its external surface. Schultze ('97) found in a pig embryo 2–3 neuromeres in the mesencephalon. Johnson ('09) represents two in this region of the pig embryo. The ventral zone of the mesencephalon is thickened causing a prominent external elevation just anterior to the origin of the oculomotor nerve.

Rhombencephalon. The conventional divisions of the rhombencephalon are not so well differentiated as those previously described. The isthmus (*Isth.*) is the constricted portion in the region of the plica-rhombomesencephalica. The metencephalon (*Meten.*) is the portion immediately following the isthmus, already considerably dilated to either side and presenting a developing fold in its ventral wall, the pontine flexure. The myelencephalon (*Myelen.*) may be arbitrarily bounded from the metencephalon by a line passing transversely across the brain near the posterior extension of the pontal flexure. From here the myelencephalon extends posteriorly arching over the cervical flexure to merge with the spinal cord. The part of the metencephalon from which the cerebellum will later develop does not show any differentiation except a local thickening of the epithelium. The roof plate is thin and considerably expanded. The lateral walls of both metencephalon and myelencephalon are indented by nearly transverse furrows (neuromeres) involving both dorsal and ventral zones. Six appear in the anterior two-thirds of the rhombencephalon. A large probably composite neuromere is found in the posterior third (myelencephalon) over the cervical flexure. Bradley ('04) has described a neuromere occurring in the region of

the cerebellum of the pig embryo. In younger pig embryos I have seen neuromeres in the rhombencephalon anterior to those here described. The cranial nerves have been found to be intimately associated with the brain wall underlying these neuromeres.

Spinal cord. The spinal cord (*Med. sp.*) shows a differentiation into dorsal and ventral zones, and also indications of neuromeric grooves. McClure ('89) called attention to the neuromeres, "myelomeres,' of the spinal cord.

CRANIAL NERVES

Nn. olfactorius and opticus. Fiber tracts for the olfactory apparatus, and for the eye have not developed.

N. thalamicus. A small elongated clump of ganglion cells (*N. th.*) were found on either side of the diencephalon dorsal to the corresponding optic vesicle. Between the ganglion and the optic vesicle passes the nasal branch (*N. na.*) of the ophthalmic nerve. No connection between the nerve and ganglion was found. From the dorsal end of the ganglion, fibres could be traced for a very short distance into the mesenchyma. It probably represents a portion of the neural crest corresponding to the nervus thalamicus of Miss Platt, which was found by growth of the brain wall, to lie directly above the eye stalk (Platt '91, pp. 97–98). It is possible that this ganglion may contribute to the formation of the ciliary ganglion which has been found by Dixon ('96), to develop in this locality. He, however, is inclined to consider the ciliary as a sympathetic derivative.

N. oculomotorius. The oculomotor nerve (*N. oc.*) arises from the thick ventral zone of the mesencephalon by several small rootlets. It extends anteriorly, laterally and ventrally to a developing eye muscle situated lateral to the infundibular region, posterior to the eye vesicle and medial to the anterior cardinal vein.

N. trochlearis. The rootlets of the trochlearis (*N. troch.*) are small and are not grouped to form a definite bundle. They leave the brain at the dorsal border of the isthmus and can be traced only a short distance.

N. trigeminus. The trigeminal nerve (*N. tri.*) consists of a sensory (portio major) and a lateral motor division (portio minor).

It is conspicuous on account of the large semilunar ganglion (*G. sl.*) connected with it. It gives rise to three branches, the ophthalmic, the maxillary and the mandibular. The ophthalmic leaves the anterior ventral portion of the ganglion and soon gives off a dorso-laterally directed nerve, the frontal (*N. fr.*) which is related to the ectoderm in the immediate vicinity. A small clump of cells is connected with the nerve near its termination. In front of the right semilunar ganglion, and just above the termination of the frontal there is another small group of cells. A corresponding group on the left did not exist. Beyond the frontal, the nasal division (*N. na.*) of the ophthalmic extends anteriorly and dorsally above the eye stalk.

The maxillary (*N. mx.*) arises from a considerable ventral lobe of the semilunar ganglion, and extends into the maxillary process of the first arch behind the lachrymal groove. As scattered fibres it can be traced as far ventrally as the optic stalk.

The mandibular (*N. md.*) extends, from the posterior ventral border of the ganglion, laterally and ventrally to the mandibular process (*Mdb.*) of the first arch. It can be followed some distance below the angle of the mouth. It contains the portio minor or motor part of the trigeminal.

The sensory roots of the trigeminal enter the brain opposite the first and second of the rhombic neuromeres represented for this embryo. The motor fibres arise from the neuroblasts situated in the basal portion of the same neuromeres.

N. abducens. The abducens (*N. abd.*) arises from the ventral zone of the fourth rhombic neuromere directly medial to the lower end of the otocyst (*V. aud.*). That on the right side shortly after it leaves the brain possesses a small aberrant branch coming from the region of the glossopharyngeus or vagus. The nerve extends anteriorly to a dense mass of cells separated from the semilunar ganglion by the anterior cardinal vein.

N. facialis. The motor roots of the facial arise from neuroblasts in the ventral zone of the third rhombic neuromere. At their origin the rootlets are somewhat separated, but as they issue from the metencephalon, they are four or five in number. They soon converge to a single bundle which passes

along the posterior border of the geniculate ganglion (*G. gn.*), and extends posteriorly and laterally along the posterior border of the first entodermal pouch, in intimate association with a bundle of sensory fibres issuing from the neuroblasts of the geniculate ganglion. Just behind the closing plate of the first pouch the associated bundles divide into a posterior and an anterior division, the facial and the chorda tympani (*N. ch. tymp.*) respectively. The facial can be traced for a short distance into the hyoid arch. The chorda tympani winds around the ventral process of the first entodermal pouch and enters the mandibular process. The geniculate ganglion (*G. gn.*) is an elongated mass of cells. It extends from the median surface of the dorsal diverticulum of the first pharyngeal pouch, to which it is for a distance closely applied, to a level of the middle of the otocyst. Its fibres, the intermedius, enter the metencephalon in the dorsal zone at the posterior border of the third rhombic neuromere under cover of the entering roots of the acustic ganglion (*G. acus*). From the ventral tip of the geniculate ganglion a small nerve massed with cells, passes anteriorly and ventrally along the dorsal median border of the auditory pouch. This is the great superficial petrosal.

N. acusticus. The ganglion of the auditory nerve (*G. acus.*) is an elongated mass of cells closely applied to the middle anterior median border of the otocyst. In the middle portion where an upper group of fibres to the ear will later appear, the ganglion is fused with the epithelium of the otocyst. From the ventral end of the ganglion a small nerve extends posteriorly to the epithelium of the lower median portion of the otocyst. According to Streeter ('08), this later will innervate the posterior ampulla and the saccule. The entering fibres from the extreme dorsal part of the acustic ganglion pass into the dorsal zone of the metencephalon opposite the third rhombic neuromere as two rootlets just above the entering intermedius.

N. glossopharyngeus. The glossopharyngeal (*N. glos.*) like the vagus to be described presently is characterized by possessing two ganglia, the ganglion superius (*G. sup.*), and the ganglion petrosum (*G. petros.*). The latter is more sharply outlined than

the former and intimately connected at its lower end with the posterior border of the dorsal diverticulum of the second pharyngeal pouch, and the adjacent ectoderm. This nerve possesses both sensory and motor fibers. The more numerous sensory rootlets are covered with ganglion cells continuous with those of the superior ganglion. They enter the dorsal zone of the myelencephalon opposite the fifth rhombic neuromere. A ganglion crest or bridge still connects the superior ganglion with the jugular ganglion (*G. jug.*) of the vagus. The motor fibres arise from neuroblasts in the mantle layer of the ventral zone of the fifth rhombic neuromere. They extend laterally through the marginal velum of the brain and emerge as a number of small rootlets ventral to the sensory components. The glossopharyngeal divides distally sending a branch, the tympanic (*N. tymp.*), down over the dorsal diverticulum of the second pharyngeal pouch into the hyoid arch. Posterior to the dorsal diverticulum it divides into two small branches, an anterior, the lingual ramus and a posterior, the pharyngeal ramus.

N. vagus. The vagus (*N. vag.*) possesses a dorsal ganglion the jugular (*G. jug.*) and a ventral one, the ganglion nodosum (*G. nodos.*) The jugular ganglion is large and is connected with an extensive posterior portion, a part of the neural crest, which ends in an S-shaped group of cells. The cells in the posterior limb of the S are more compact than those in the anterior limb, and fibres from its dorsal apex enter the brain as a distinct root. The ganglionic crest connecting with the jugular, is the undifferentiated representative of several ganglia, companions of groups of the more ventral roots composing the hypoglossal nerve (*N. hyp.*). The jugular ganglion is also continuous with cells which overlie the sensory roots quite close to their entrance to the brain. These roots are here represented diagrammatically. The ganglion nodosum is also quite elongated, and is covered externally to a considerable extent by vagus fibres. It is connected intimately with the ectoderm of the posterior wall of the fourth ectodermal groove.

The vagus contains both sensory and motor fibres. The sensory fibres arise from cells of the jugular ganglion, including the ganglionic crest. The motor components arise in part from neuroblasts

in the dorso-lateral part of the ventral zone of the sixth rhombic neuromere. These fibres leave the brain under the entering sensory roots. Another portion of its motor fibres are derived from the spinal accessory to be described presently. Posterior to the third pharyngeal pouch the vagus gives off an anterior branch the superior laryngeal (*N. lary'g. sup.*). Beyond this it passes behind the pulmonary arch and can be traced for a distance where it is ventral and lateral to the oesophagus. The auricular and recurrent branches of the vagus are not formed in this embryo.

N. accessorius. The spinal accessory (*N. acc.*) is derived from small rootlets issuing from the dorso-lateral part of the ventral zone of the myelencephalon and the spinal cord as far posteriorly as the sixth cervical ganglion. Caudally the rootlets issue from the spinal cord below the main trunk of the accessory and much nearer the ventral roots than they do more anteriorly, showing somewhat of a gradual transition into ventral roots. Lubosch ('99) who has made a comparative study of the accessory nerve, concludes that as a general rule its more posterior rootlets are nearer the dorsal roots of the spinal ganglia. Exceptions, however, to this rule were noted (pp. 530 and 545). The spinal accessory composed of only a few fibres in its posterior part, gradually increases in caliber as it extends forward under the spinal ganglia. It finally turns ventrally along the posterior border of the vagus. Below the jugular ganglion it becomes closely connected with the vagus, contributing to its (vagus) motor part. A portion of the accessory, however, bends dorsally, away from the vagus for the later innervation of the trapezius and sternomastoid muscles.

N. hypoglossus. The hypoglossal (*N. hyp.*) is a composite motor nerve arising by several rootlets from the ventral part of the ventral zone of the myelencephalon. These rootlets soon converge to form the main trunk. The corresponding dorsal ganglia are represented by an undifferentiated portion of the neural crest which, however, shows indications of ganglion formation in its posterior part.

SPINAL NERVES

Portions of the anterior five cervical nerves (*Nn. sp. 1–5.*) and their ganglia are shown in the reconstruction. The ganglia are still joined together by portions of the neural crest. Ganglion cells continuous with those of the spinal ganglia cover the sensory rootlets close to their entrance into the spinal cord.

SENSE ORGANS

The extent of the nasal invagination is represented in fig. 2. It is a shallow laterally compressed pit (*F. na.*). Its thickened epithelium does not reach the wall of the oral cavity.

The right optic vesicle (*V. op.*) with its connecting stalk is represented in fig. 3. It is cup-shaped on its lateral surface except for a groove which leaves the cup, and extends along the border of the stalk toward the brain. The lens is still connected with the ectoderm by a slender stalk cut across in the drawing.

The otocyst (*V. aud.*) is also represented in fig. 3. It is an oval ectodermal vesicle lying adjacent to the lateral surface of the rhombencephalon. Above it projects the ductus endolymphaticus which arises from its median dorsal surface.

VASCULAR SYSTEM

Heart. In fig. 1 the heart is represented as sectioned on the left side of the median line. The trabeculae of the ventricle here as also in fig. 2, are represented diagrammatically. The left atrium is now largely separated from the right by the septum primum (atrial septum) united ventrally with two thickenings of the atrial canal. Between these thickenings a small ventral passage still persists which unites the two atria. It is the interatrial foramen (*F. ia.*). A secondary opening in the septum primum the foramen ovale (*F. o.*) occurs more anteriorly and dorsally.

In the posterior median part of the left atrium there is a small opening marking the outlet of the single pulmonary vein (*V. pul.*). Ventral to this vessel the left common cardinal vein is cut

obliquely. Between the left atrium and the corresponding ventricle a median antero-posterior ridge formed by the union of the thickenings of the artial canal, represent the anlage of the right portion of the bicuspid valve. Immediately ventral to this ridge there is a large opening, the interventricular foramen (*F. iv.*) bounded ventrally by the free edge of the ventricular septum. Through this opening the two ventricles communicate. Later in development it comes to open into the ventral aorta (*Ao.v.*) by the union of the aortic and ventricular septa. The aortic septum is already indicated in the aortic bulb, fig. 2, by two folds or ridges, *a* and *b*. The ventricular septum connects with the left fold (*b*) while the one on the right (*a*) connects with the right ventricular wall just anterior to the atrio-ventricular foramen. The left ventricle already has a much thicker wall of muscular trabeculae than the right.

In fig. 2. the heart is sectioned on the right of the median line. Into the right atrium (*At. d.*) opens the sinus venosus (*S. v.*) between its two valves which unite anteriorly and extend along the atrial wall as a ridge, the septum spurium. The atrium opens into the corresponding ventricle by the right atrio-ventricular foramen. On the right side of this foramen is figured the anlage which contributes to the formation of the tricuspid valve. The right ventricle opens into the bulbus arteriosus. This outlet is being subdivided by the formation of the aortic septum as already described. The permanent outlet will be through the pulmonary trunk which as indicated in the figure, leaves the antero-ventral part of the ventricle and passes dorsally and medially across the first portion of the aortic channel.

Arteries. The arteries are figured in figs. 1 and 2. In fig. 2 the ventral aorta (*Ao. v.*) after leaving the heart is seen to give off on the left five aortic arches one to each visceral arch. Their relation to the pharyngeal pouches is clear. The slender first and second arches on either side arise from a common trunk as the ventral aorta bifurcates just behind the median thyroid (*Th. med.*). In fig. 1 the corresponding aortic arches on the right are represented as showing through the pharyngeal wall. The intermediate portion of the second arch on the right has become

obliterated. The most posterior or pulmonary arches on account of the developing aortic septum leave the aorta by a short common trunk. A little above the bifurcation of this trunk each pulmonary arch gives off posteriorly a small pulmonary artery (*A. pul.*). The right pulmonary artery arises from the corresponding arch by two small branches. The aortic arches of each side extend around the lateral border of the pharynx and join the descending aorta (*Ao. desc.*) of the corresponding side. The two descending aortae extend caudally and unite near the cardiac end of the stomach to form the median dorsal aorta (*Ao. med. dor.*). Each descending aorta from where it is joined by the first aortic arch is continued anteriorly into the maxillary arch posterior to the optic stalk. This represents a portion of the internal carotid artery (*A. car. int.*). It gives off a branch above the optic stalk which represents the anterior cerebral artery. It is here joined by the posterior communicating branch (*A. com. post.*) of the basilar (*A. bas.*) which gives off in front of the oculomotor nerve the posterior cerebral. Caudal to the posterior communicating branches the anterior part of the basilar is a single vessel and gives off several lateral branches, but along the greater part of the pontine bend it is represented by two vessels intimately connected by cross branches. From each of these vessels numerous branches extend laterally. Posteriorly these two longitudinal vessels merge with a complicated system of capillaries spreading along the ventral and lateral surfaces of the spinal cord.

Six intersegmental arteries arise from each descending aorta (*Ao. desc.*). From the median dorsal aorta corresponding pairs are given off at regular intervals along its course to the tail. Those on the left are represented as cut away. Each intersegmental artery extends from the aorta dorsally and laterally to the lateral surface of the spinal cord alongside the corresponding spinal nerve. From the seventh intersegmental artery the most anterior of those arising from the median aorta, a lateral branch, the subclavian extends into the upper limb-bud. A series of ventrolateral branches from either side of the aorta extend to the glomeruli of the corresponding mesonephros.

The most anterior of the median ventral branches of the aorta is the coeliac axis (*A. coel.*) which arises opposite the pyloric end of the stomach. The omphalo-mesenteric (*Aa. omp. mes.*) is represented by three median branches which anastomose in several places. In their course to the yolk sac, they cross the intestine on the right and give off branches to the mesentery. The two anterior roots of the omphalo-mesenteric will later atrophy the posterior persisting to form the superior mesenteric artery. In a human embryo of 5 mm. Tandler ('03), found that the omphalo-mesenteric artery was represented by four or five median branches from the aorta. These united to form a ventral longitudinal anastomosis extending downward in front of the aorta. Later in development all these roots disappeared with the exception of the posterior one which formed the main stem of the superior mesenteric artery.

Each common iliac (*A. Il. com. d. and s.*) arises from the aorta by two short rootlets (cut off on the left) and extend laterally and ventrally to the region of the posterior limb-bud to which it gives off a branch, the external iliac. It then continues forward and passes into the umbilical cord as the umbilical branch. The original vessels which connected the umbilical arteries with the latero-ventral wall of the aorta are now represented by a single trunk (*A. mes. inf.*) just anterior to the origin of the iliacs. This soon divides after leaving the aorta into right and left branches each of which can be traced ventrally through a strand of tissue passing across the posterior part of the coelom to the corresponding umbilical branch. This vessel which earlier represented a part of the umbilical arteries apparently becomes the inferior mesenteric artery of the adult.

Veins. The vitelline vein (*V. vi.*, fig. 1.) arising on the surface of the yolk sac passes into the mesentery and extends parallel with the first limb of the intestinal loop, finally crossing it on the left a little posterior to the pancreas. Here it is joined by another vein of about the same caliber, the superior mesenteric (*V. mes. sup.*) which arises in the mesenchyma of the mesentery by numerous tributaries. The common trunk known as the portal vein (*V. p.*) divides into two branches corresponding to the original right and

left vitelline vessels. The left branch is small. It passes on the left of the dorsal pancreas where it is resolved into a plexus of small vessels extending in the mesenchyma of the mesogastrium. It originally extended on to the liver. The right branch extends anteriorly between the ventral pancreas below and a subdivision of the dorsal pancreas above. It then bends to the right and enters the liver (*V. p.*, fig. 2). In the liver it opens into the sinusoids which represent subdivisions of the vitelline veins, (Minot,' 00).

The umbilical veins secondarily have acquired an opening into the hepatic sinusoids. The right (*V. um. d.*) represented in fig. 2, anastomoses with the larger one on the left within the cord. It then passes anteriorly through the somatopleure of the ventral body wall, receiving tributaries in its course from the posterior limb-bud and body wall. It finally enters the liver and breaks up into the hepatic sinusoids. The left umbilical upon entering the liver passes, as a large channel, the ductus venosus (*D. v.*) through the sinusoids toward the heart.

From a plexus of veins overlying each dorso-lateral surface of the prosencephalon from which the superior longitudinal sinus will later develop a lateral branch extends on either side across the diencephalon. The one on the right is here represented. Dorsally this is joined by several veins coming from the region of the mid-brain, isthmus and anterior part of metencephalon. Ventrally it is joined by the ophthalmic vein (*V. oph.*) which arises from a plexus in the mesenchyma near the nasal epithelium, and coursing along under the lachrymal groove receives branches from the region of the eye. The part of the anterior cardinal (*V. card. ant.*) formed by these branches is internal to the semilunar ganglion and has been called the cavernous sinus. The anterior cardinals then extend posteriorly, lateral to the ventral wall of the rhombencephalon and outside the otocyst and cranial nerves with the exception of the hypoglossal which as it passes forward crosses the vein on its outer side. Behind the otocyst each anterior cardinal receives a large branch proceeding from a plexus of capillaries overlying the lateral surface of the myelencephalon. Posteriorly it passes to the common cardinal vein (*V. card. com. d.*). Just anterior to the common cardinal its dorsal

wall is connected with an anastomosing plexus of vessels with which the most anterior intersegmental veins unite. While ventrally it receives the linguo-facial vein (*V. ling.-fac.*) (Grosser '01, Lewis '03 and '09) arising on the corresponding side of the branchial arches. Posterior to the opening of the linguo-facial vein, from the median side of each anterior cardinal, small branches extend in front of the trachea. These eventually will form the vena anonyma sinistra.

The anterior and posterior portions of the right posterior cardinal (*V. card. post.*) are well defined. In the region of the mesonephric tubules it has been divided into Wolffian sinusoids (Minot '00), and its course along the dorsal border of the Wolffian body has been interrupted in places. Into the ventral wall of the persisting portions of the vein enter numerous sinusoids which extend around the lateral side of the metanephros. Four of these are represented in the drawing. In a similar manner a series of sinusoids earlier passed around the mesial side of the metanephros and connected with the posterior cardinal. Between these median sinusoids there now has formed on either side a longitudinal anastomosis, the subcardinal vein (*V. scard. d.*), (Lewis '02). The dorsal portions of some of the median sinusoids on the right are seen, either connecting the subcardinal and posterior cardinal or upon the interruption of the latter, taking over to the sub-cardinal the thus isolated parts with the entering intersegmental veins. The ventral portions of the median sinusoids have in part atrophied. The subcardinal on the left connects anteriorly with the posterior cardinal. The subcardinal on the right which forms a part of the inferior vena cava has made a secondary connection with the ductus venosus by a "tapping of the hepatic sinusoids" (Lewis, '02). Its connection with the corresponding posterior cardinal has been lost, and its anterior extremity is now a small branch arising from its dorsal wall near where it bends toward the liver. At the lower border of the liver a small sinusoidal connection with the subcardinal is seen. Between the right and left subcardinals twelve places of anastomosis were found. The four posterior, situated a little below the posterior or permanent root of the omphalo-

mesenteric artery, probably coalesce to form the large renal anastomosis represented for the 12 mm. pig embryo by Lewis.

It also seems probable that in the pig between the subcardinal and posterior cardinal divisions of the inferior vena cava there is formed an intermediate portion also from Wolffian sinusoids, but dorsal to the mesonephric arteries and medial to the posterior cardinal. An indication of this vessel is shown united anteriorly with the subcardinal by a broad connection but with slender cross connections posteriorly. The posterior cardinal in this region is slender and its continuity in places is lost. The right subclavian vein (*V. scl. d.*) arises from the posterior cardinal between the seventh and eighth intersegmental vessels.

A large vein from the liver, the vena hepatica communis (*V. hep. com.*) extends anteriorly, and unites with the right and left common cardinal veins to form the sinus venosus which opens into the right atrium as already described.

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EXPLANATION OF FIGURES

ABBREVIATIONS FOR FIG. 1

All.	allantois
Ao. cau.	aorta caudalis
Ao. desc.	Ao. descendens
Ao. med. dor.	Ao. mediana dorsalis
Arc. aor. 4	arcus aorticus quartus
Arc. pul.	arcus pulmonalis
A. bas.	arteria basilaris
A. car. int.	A. carotis interna
A. coel.	A. coeliaca
A. com. post.	A. communicans posterior
A. il. com. d.	A. iliaca communis dextra
A. il. com. s.	A. iliaca communis sinistra
A. mes. inf.	A. mesenterica inferior
Aa. omp.-mes.	Aa. omphalo-mesentericae
Ch. d.	chorda dorsalis
Cl.	cloaca
Dien.	diencephalon
D. W.	ductus Wolffii
Epgl.	epiglottis
F. ia.	interatrial foramen
F. iv.	foramen interventriculare
F.o.	foramen ovale
Hyp.	hypophysis
Int.	intestine
Isth.	isthmus
M.	mouth
Mdb.	processus mandibularis
Med. sp.	medulla spinalis
Mesen.	mesencephalon
Met.	metanephros
N. sp. sec.	nervus spinalis secundus
Neu.	a neuromere
Oe.	oesophagus
Panc. d.	pancreas dorsale
Panc. v.	pancreas ventrale
S.P.	Seesel's pocket
St.	stomach
Telen	telencephalon
Th. med.	thyreoidea mediana
T. i.	tuberculum impar
Tr.	trachea
Um. C.	umbilical cord
V. hep.	vena hepatica
V. mes. sup.	V. mesenterica superior
V. p.	V. portae
V. pul.	V. pulmonalis
V. vi.	V. vitellina
x.	pharyngeal diverticulum
Yk. S.	yolk stalk

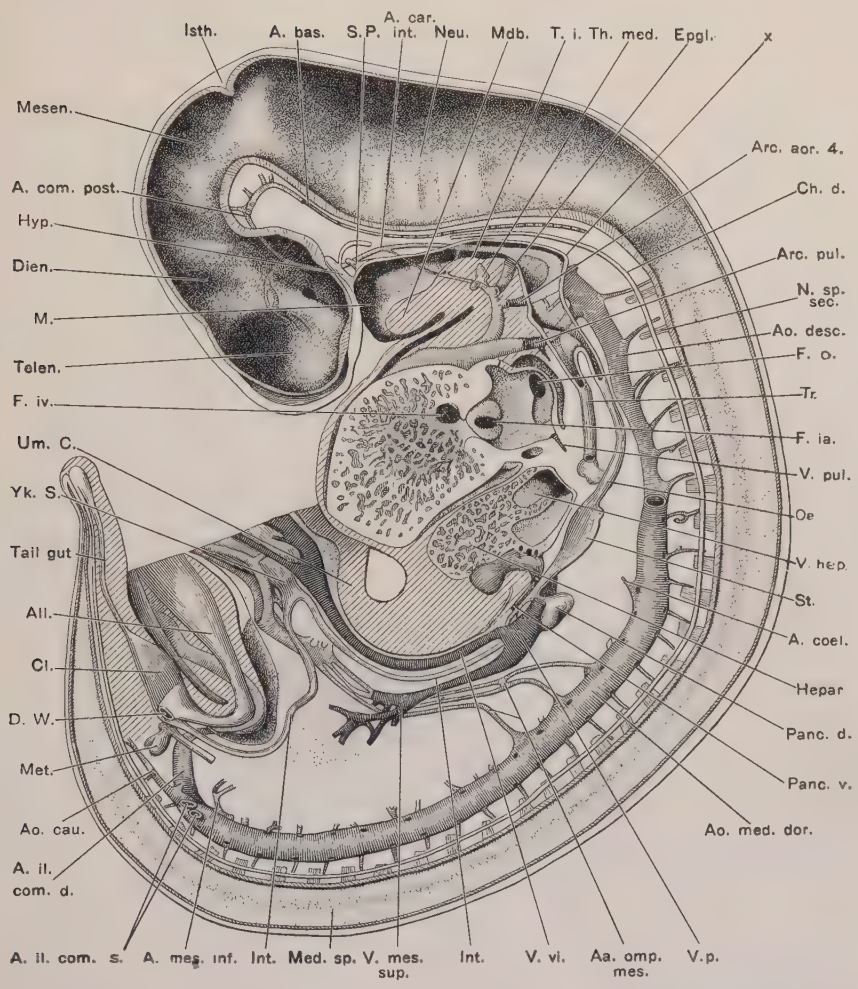

Fig. 1 Reconstruction from a pig embryo of 7.8 mm. (Harvard Embryological Collection 1358). The drawing illustrates especially the arterial system and the epithelial portion of the digestive tract and its appendages. It also shows the left atrium and ventricle of the heart, and the interior of the brain and spinal cord. × .15 diams.

ABBREVIATIONS FOR FIG. 2

a.	right fold or ridge of aortic septum
Ao. desc.	aorta descendens
Ao. v.	aorta ventralis
A. car. int.	arteria carotis interna
Aa. mes.	Aa. mesonephricae
A. pul.	A. pulmonalis
At. d.	atrium dextrum
b.	left fold or ridge of aortic septum
Ch. d.	chorda dorsalis
D. v.	ductus venosus
D. W.	ductus Wolffii
F. na.	fossa nasalis
Med. sp.	medulla spinalis
Mes.	mesonephros
Mesen.	mesencephalon
Met.	metanephros
Meten.	metencephalon
Myelen.	myelencephalon
Ph. P. 1, 2, 3, 4	pharyngeal pouches 1–4
S. v.	sinus venosus
Th. med.	thyreoidea mediana
V. card. ant.	vena cardinalis anterior
V. card. com. d.	V. cardinalis communis dextra
V. card. com. s.	V. cardinalis communis sinistra
V. card. post.	V. cardinalis posterior
V. hep. com.	V. hepatica communis
V. is.	V. intersegmentalis
V. ling.-fac.	V. linguo-facialis
V. oph.	V. ophthalmica
V. p.	V. portae
V. scard. d.	V. subcardinalis dextra
V. scl. d.	V. subclavia dextra
V. umb. d.	V. umbilicalis dextra
Ven. d.	ventriculus dexter

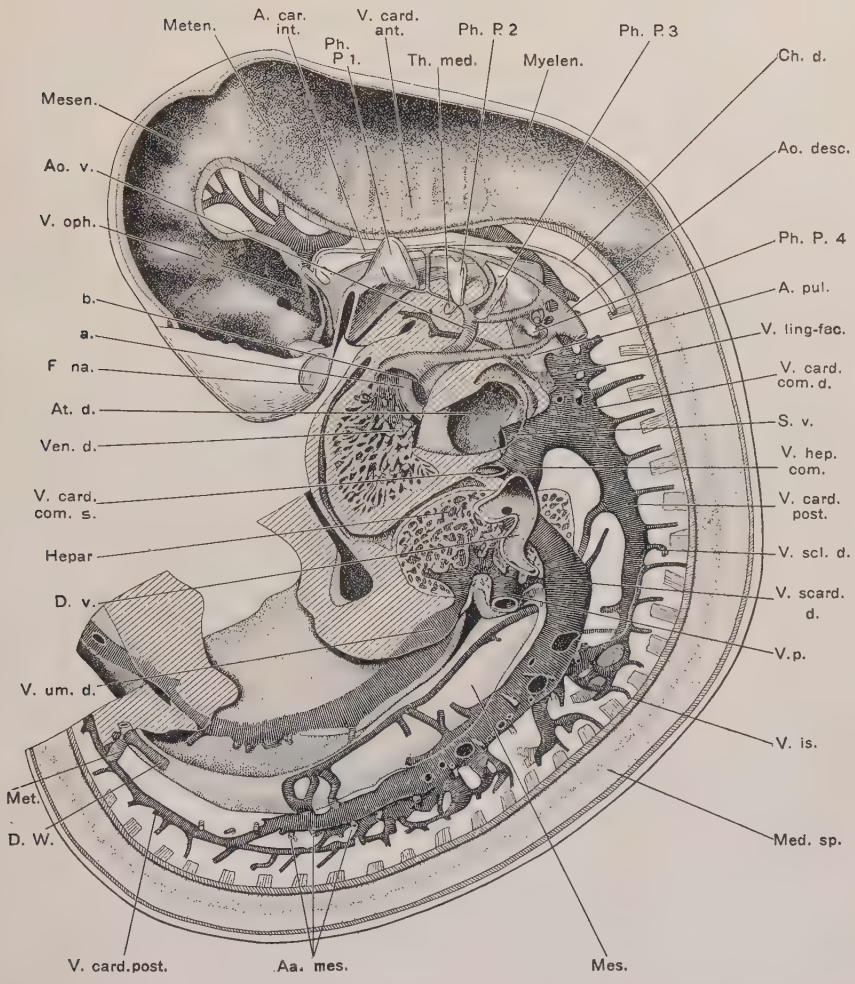

Fig. 2 Reconstruction from a pig embryo of 7.8 mm. (H. E. C. 1358) It represents chiefly the venous system of the right side, and the right atrium and ventricle of the heart, and shows the relation of the aortic arches and pharyngeal pouches of the left side. × .15 diams.

ABBREVIATIONS FOR FIG. 3

Dien.	diencephalon	*N. glos.*	N. glossopharyngeus
D. acus.	ganglion acusticum		
G. gn.	G. geniculatum	*N. hyp.*	N. hypoglossus
G. jug.	G. jugulare	*N. lary'g. sup.*	N. laryngeus superius
G. nodos.	G. nodosum	*N. md.*	N. mandibularis
G. petros.	G. petrosum	*N. mx.*	N. maxillaris
G. sl.	G. semilunaris	*N. na.*	N. nasalis
G. sup.	G. superius	*N. oc.*	N. oculomotorius
Mdb.	processus mandibularis	*Nn. sp.*	Nn. spinales 1–5
		N. th.	N. thalamicus
Med. sp.	medulla spinalis	*N. troch.*	N. trochlearis
Mesen.	mesencephalon	*N. tymp.*	N. tympanicus
Meten.	metencephalon	*N. vag.*	N. vagus
Myelen.	myelencephalon	*S. cer.*	sinus cervicalis
N. abd.	nervus abducens	*Telen.*	telencephalon
N. acc.	N. accessorius	*V. aud.*	vesicula auditiva
N. ch. tymp.	N. chorda tympani	*V. op.*	vesicula optica
N. fr.	N. frontalis		

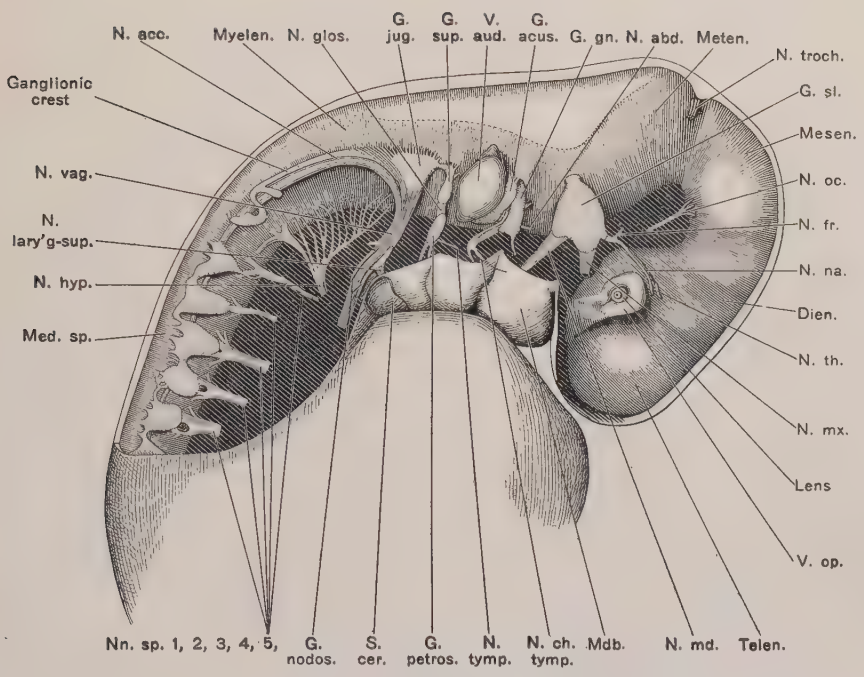

Fig. 3 Reconstruction to show the branchial arches, the exterior of the brain, and the cranial nerves of a pig embryo of 7.8 mm. (H. E. C. 1358) × .15 diams.

A NOTE ON THE SOURCE AND CHARACTER OF THE EARLY BLOOD VESSELS OF THE KIDNEY

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THREE FIGURES

The remarkable change in position which is undergone by the permanent kidney in its development carries with it a corresponding change in its blood supply. Shifted gradually upward from the pelvis to the upper abdomen, the metanephros attains its normal position characteristic in the adult in embryos measuring 20 mm. to 30 mm. in length. In an analogous manner it derives its blood supply from higher and higher sources; at first delicate capillaries from neighboring pelvic trunks nourish the renal gland, then, in its migration upward, vessels from the abundant anastomoses present undertake the rôle, and finally the Wolffian body artery, near the twenty-first aortic segment—as Broman has recently shown—becomes the permanent renal artery.

This is apparently an entirely new conception. Hochstetter, working with ordinary serial sections of uninjected embryos, stated that the kidney does not receive its renal artery and vein until it reaches its permanent position. Pohlman expressed a similar view, even maintaining that the kidney is not vascularized until then. Hill, who injected only the main blood vessels and used the Schultze method of clearing came to the same conclusion; for by such a method the kidney has reached its adult position before large blood vessels supplying it can be seen.

The above observation on the permanent renal artery and vein is true in a very literal sense, *i.e.*, the kidney neither receives its definitive arterial supply nor its permanent venous channel until it reaches its normal position, in man, in embryos, measuring

THE ANATOMICAL RECORD, VOL. 5, NO. 2.
FEBRUARY, 1911.

20 mm. in length. An entirely erroneous idea, however, of the development of the renal blood vessels has arisen from this fact, for not only would this seem to indicate that the renal vessels came suddenly into existence when the kidney attained its permanent position, but that it was not vascularized until then, notwithstanding its growth and differentiation. If the latter were true the early renal tissue would differ in this respect from other embryonic tissues, as recent studies in this laboratory have shown that all embryonic organs, with the exception of few non-vascular areas, have abundant minute vessels supplying them.

Broman, questioning the old idea, made a careful examination of the early metanephric tissue and found numerous capillaries present. Some of these were traced to the posterior cardinal veins, while others led to the venae revehentes of the Wolffian body. He suggests from this the possibility of a renal portal circulation for the early metanephros of mammals, which condition exists, as is well known, in adults of the lower vertebrates and in embryos of the higher ones. Since the direction of the blood-flow is not disclosed, this is of course not established.

Only under most favorable conditions, however, are the capillary connections and channels seen in tissue prepared by the usual method for histological study. For a complete survey of the vascular system of any area or organ the injection of living embryos is necessary and this method has yielded an abundance of new facts in many areas and calls for a reworking of the history of the renal vessels. Consequently, at the suggestion and encouragement of Dr. Evans, I have studied the early renal blood supply in several injected pig embryos. I have been able to use injections much more complete in younger stages than those accessible to Dr. Hill who had previously considered the subject in this laboratory. For these, I wish to thank Dr. Evans who placed several perfect series of injected embryos at my disposal. The present note is intended as a preliminary report of the study which I hope to extend subsequently, but the results derived from a careful examination of a single stage in which a very beautiful and complete injection was secured seems of sufficient interest to publish briefly now.

The embryos which I have examined confirm the existence of an abundant capillary supply for the renal anlage, but do not prove a renal portal current since several arterial sources for the renal plexus are clearly shown.

Three embryos of the pig 14 mm. in length were studied. Of these, one was cut transversely in sections 50 μ thick, the other two in sagittal sections 30 μ thick. From one of the latter, no. 1300 of the collection, which shows a particularly good injection, the accompanying figures were made. In pig embryos of this size the A. mesenterica inferior, soon after its origin from the aorta, gives off several small caudally directed branches which immediately form a fine capillary plexus and anastomose with a mass of capillaries permeating the mesenchyme surrounding the renal anlage. The latter plexus constitutes the primary metanephric plexus and can be seen in embryos measuring 10 mm. in length, but its character is still largely capillary in the 14 mm. embryos studied.

After the aorta gives off the right and left hypogastric arteries it continues caudal and medianward as the small A. sacralis media, which gives off besides the usual dorsal segmental branches (1) several ventral branches which form a plexus in the region of the ureter, cloaca and hind-gut and (2) a number of small lateral branches anastomosing to form a plexus on the ventral surface of the scleromeres. Direct connections exist between each of these plexuses with the renal plexus.

Two arterial sources for the early metanephric capillary plexus are thus shown to exist, one from the A. mesenterica inferior and the other from the A. sacralis media.

As for the drainage of this plexus, both transverse and sagittal sections show clear connections with the posterior cardinal veins, the inferior mesenteric veins and the Wolffian body veins. If these are all to be looked upon as drainage vessels, which they in all probability are, the capillaries joining the posterior cardinal veins form an inferior venous outlet for the plexus, comparable to the lower arterial source from the A. sacralis media; the connections with the inferior mesenteric vein accompanying the corresponding artery at the border of the colon (fig. 2) and the

efferent Wolffian body veins constitute two paths of drainage for the upper pole of the renal anlage.

I have given a sagittal reconstruction in order to show the position of the renal anlage at this stage. Figs. 2 and 3, which show the vessels, were both drawn at a magnification of two hundred and fifty diameters and appear here greatly reduced. The reconstruction (figs. 2 and 3) was made by superposing accurate drawings of projections of each of the sections at the above magnification. The drawings were in each case corrected by a reëxamination of the field with the highest dry lens, so that in this way practically all the vessels present in the area were plotted. The caudally directed branch of the inferior mesenteric artery which reaches the renal anlage could be seen in its entirety in one of the sections shown in fig. 2.

From these studies it seems highly probable that we have here direct observations on the early source of the renal vessels, which explain for the first time some of the well known anomalies of the A. renalis in the adult. While anomalies of the renal vessel are more frequently associated with a retention of the pelvic position for the organ, they are well known to be common in kidneys which occupy their normal position, and both pelvic and normally placed kidneys, as has been known for a long time, frequently obtain their sole or at least accessory arteries from lower sources. The accessory renal arteries may arise from the middle sacral, common iliac, or inferior mesenteric artery, and not infrequently these may take the place of the renal artery proper. We have had hitherto no data,[1] as far as I am aware, which will explain the vascularization of the kidney from sources so far removed from the normal one. But with the knowledge which we now possess that at least the middle sacral and inferior mesenteric trunks supply the gland while in its early pelvic position, at least a portion of these so-called anomalies are seen to be but the retention of normal embryonic vascular relations.

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[1] Mr. Broedel, whose studies on the renal vessels have extended over many years, has been kind enough to look over my work, and it is of interest to state that he, in an unpublished work, has come to the same conclusion as regards the early renal vascular relations in man, *i.e.*, the kidney possesses abundant vascular connections during its entire time of ascent to its definitive position in the abdomen.

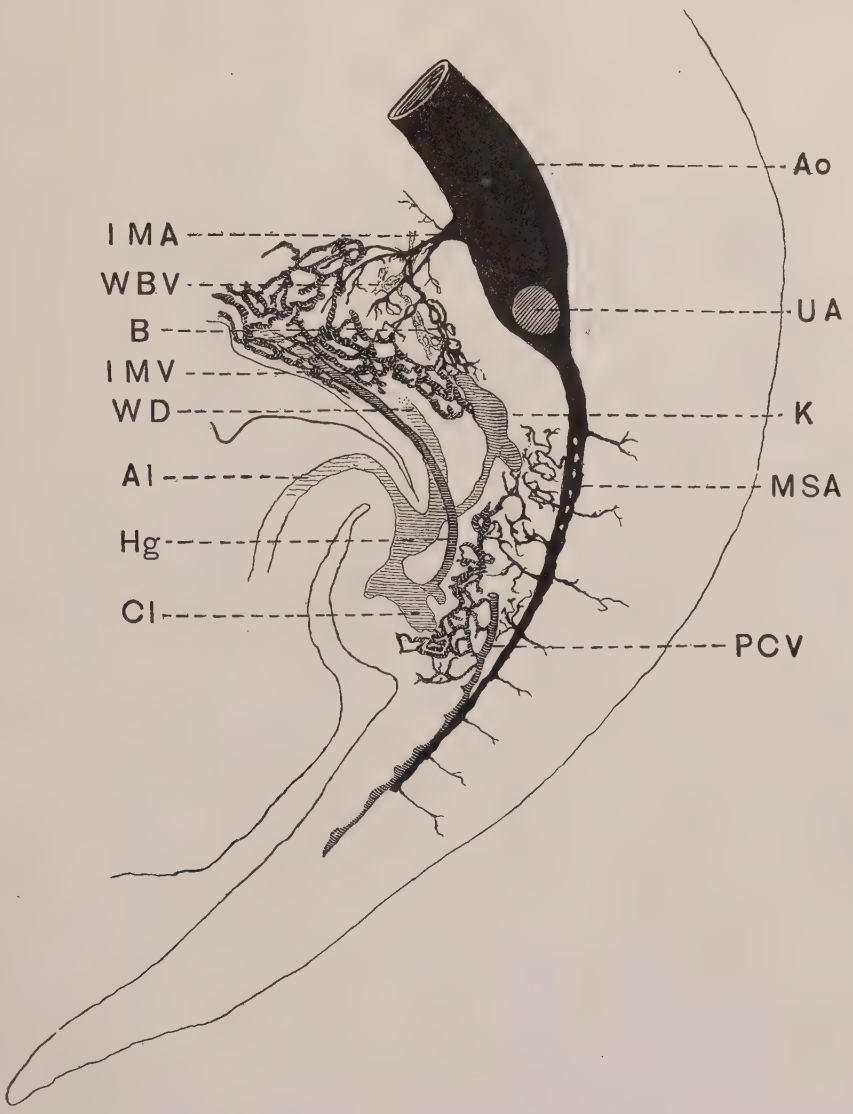

Fig. 1 Sagittal reconstruction, vessels slightly diagrammatic, to show position of renal anlage in 14 mm. pig. embryo; drawn at a magnification of 50 diameters—here shown reduced. *K* = kidney; *Ao* = aorta; *UA* = umbilical artery; *I M A* = inferior mesenteric artery; *B* = branch to renal plexus from inferior mesenteric artery; *M S A* = middle sacral artery; *P C V* = posterior cardinal vein; *W B V* = Wolffian body vein; *I M V* = inferior mesenteric vein; *Cl* = Cloaca; *Hg* = hind-gut; *Al* = allantois; *W D* = Wolffian duct.

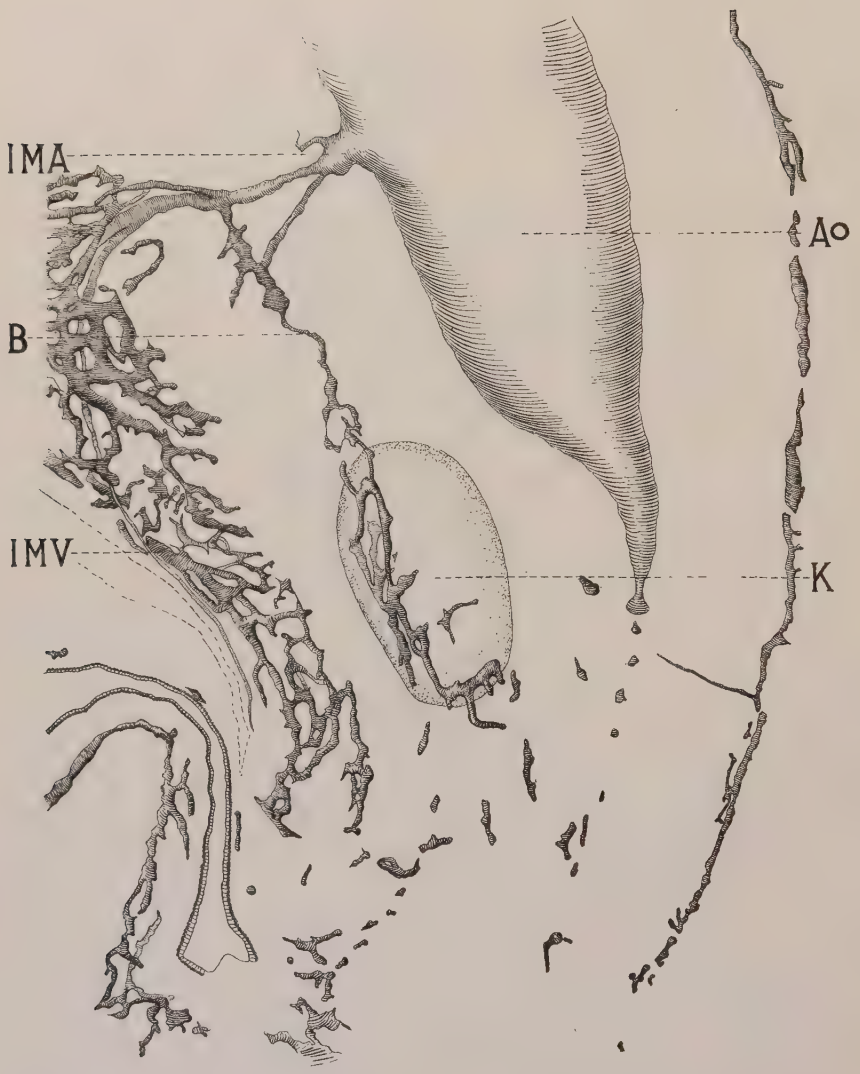

Fig. 2. Drawn from section 30μ thick of 14 mm. pig embryo at a magnification of 250 diameters, here reduced, showing in its entirety the caudally directed branch to the renal anlage from the inferior mesenteric artery. *K* = kidney; *Ao* = aorta; *I M A* = inferior mesenteric artery; *B* = branch to renal plexus from inferor mesenteric artery.

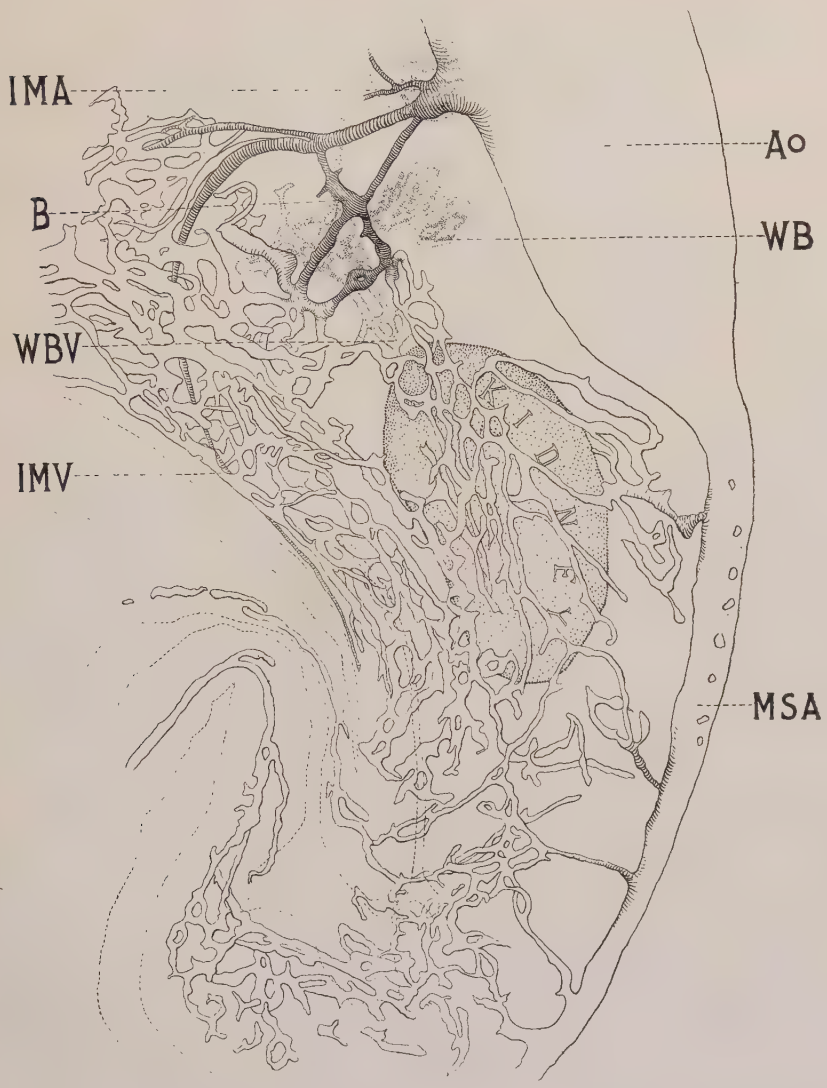

Fig. 3 Reconstruction showing renal vascular connections in 14 mm. pig embryo. Figure drawn at a 2.50-diameter magnification, here reduced. *Ao* = aorta; *I M A* = inferior mesenteric artery; *B* = branch to renal plexus from inferior mesenteric artery; *M S A* = middle sacral artery; *W B V* = Wolffian body vein; *I M V* = inferior mesenteric vein.

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COMPLETE DOUBLE URETER IN MAN

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TEN FIGURES

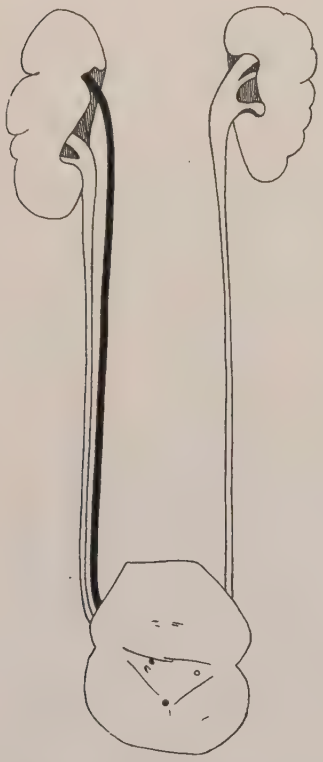
The following five cases of complete double ureter were presented before the Association of American Anatomists at Chicago in January, 1908. The specimens were also exhibited at this time. Four of these are from the anatomical laboratory of the Cornell University Medical College at Ithaca. The fifth was found in the anatomical laboratory of the Johns Hopkins University and was sent to me by Dr. A. G. Pohlman.

The first case is from a white male about forty-five years old, subject number 91 of the Cornell University series. There is no record of the cause of death. Two ureters are found on the right side (fig. 1). The pelves from which these arise are situated in two separate sinuses. These are completely isolated from one another by a well marked mass of kidney tissue. The ventral walls of these sinuses are more poorly developed than the dorsal walls, so that the ureters appear to enter somewhat from the ventral side. This is accentuated by a superior and an inferior notch corresponding to the position of each sinus.

The superior pelvis represents but one major calyx, which is divided into three minor calyces. The dilated cephalic end of the ureter as it passes into the pelvis is seen projecting but slightly beyond the ventral boundary of the sinus.

The inferior pelvis is larger and drains about three-fourths of the kidney. It projects decidedly beyond the sinus and is divided into two major calyces. These are clearly seen from the ventral surface. The cephalic major calyx has three and the caudal two subdivisions.

The ureter from the superior pelvis is about equal in size to the ureter from the inferior pelvis. It opens into the moderately dilated bladder dorso-superior as well as very slightly medial to the ureter from the inferior pelvis, as shown in figs. 1 and 2. In table 2, I have given the exact distances apart of the orifices



1

2

Fig. 1 (× ¼) Semidiagrammatic outline of case no. 1. Ventral view.
Fig. 2 (× 1) Drawing of the bladder of case no. 1, showing trigone and openings of the ureters.

of the double ureters as well as the distance of each of them from the ureter of the normal side, and from the internal urethral opening. The distance of the orifice of the normal ureter from the internal urethral opening is also given. These distances would in life be constantly changing with the filling and empty-

TABLE 1

Comparison of the pelves of the kidneys from which the double ureters arose

CASE NUMBER	SUPERIOR PELVIS			INFERIOR PELVIS			
	NUMBER OF MAJOR CALYCES	NUMBER OF MINOR CALYCES ON		NUMBER OF MAJOR CALYCES	NUMBER OF MINOR CALYCES ON		
		Cephalic major calyx	Caudal major calyx		Cephalic major calyx	Intermediate major calyx	Caudal major calyx
1	1	3		2	3		2
2	1	5		1	5		
3	1	2		3	4	1	2
4	2	1	1	2	4		3
5	1	2		2	5		2

TABLE 2

Comparison of the orifices of the ureters in the bladder

CASE NUMBER	DISTANCE APART OF THE ORIFICES OF THE TWO URETERS OF THE SAME SIDE	DISTANCE OF THE ORIFICE OF URETER OF NORMAL SIDE FROM THE ORIFICE OF THE URETER OF THE		DISTANCE OF THE INTERNAL URETHRAL ORIFICE FROM THE ORIFICE OF THE URETER OF THE		
		Superior pelvis	Inferior pelvis	Superior pelvis	Inferior pelvis	Normal side
	mm.	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*
1	3	20	20.5	22	20.5	14
2	14	31	38			
3	8	33	41	26	32	30
4	5	11	16	10	14	11
5	3	27	28	26.5	27.5	20

TABLE 3

CASE NUMBER	SUBJECT NUMBER	COLOR	SEX	AGE	SIDE OF BODY ON WHICH DUPLICATION OCCURS	SINUSES COMPLETELY SEPARATED	SINUSES CONNECTING MEDIALLY	NUMBER OF ARTERIES TO KIDNEY
1	91	W	male	about 45	right	yes	no	2
2	305	W	male	adult	right	no	yes	2
3	242	W	female	about 51	left	no	yes	1
4	258	W	male	68	right	no	yes	4
5	Hopkins	?	male	adult	left	yes	no	1

ing of the bladder and in these specimens the measurements are, of course, influenced by the degree of distention or contraction of the bladder. I believe, however, that in a given specimen the relation of the orifices to one another will remain practically the same in a contracted as in a distended bladder. From the above table it will be seen that in case no. 1 the orifices of both the ureters of the right side are farther from the internal urethral orifice than the orifice of the normal ureter.

The right kidney is 12 cm. long and 6 cm. wide at its widest point. Its surface is not entirely smooth but presents some slight remains of the embryologic lobulation, especially in the notches on its lateral border. It is supplied by two arteries. The main artery is distributed to the kidney both dorsal and ventral to the pelves. The smaller accessory artery, which arises from the aorta 6 cm. inferior to the main artery, passes to the inferior edge of the hilum and enters the inferior sinus of the kidney dorsal to the inferior pelvis. A single vein returns the blood to the inferior vena cava.

The left kidney is smaller. It measures 9.75 cm. is length and 5.5 cm. in width at its widest point. It shows decided indications of the embryonic lobulation, especially in the notching of its lateral border. The ventral wall of the sinus is markedly deficient so that the pelvis, which is large, is entirely outside of it, as shown in fig. 1. The pelvis is divided into a large superior and a small inferior major calyx. This kidney has but one main artery, and a single vein returns the blood to the inferior vena cava.

The prostatic utriculus and the openings of the common ejaculatory ducts appear to be normal. The rest of the generative organs were not preserved with the specimen.

The second case is from subject number 305 of the Cornell University series, an adult white male, age not recorded. The cause of death was given as chronic bronchitis. The double ureters are found here also on the right side (fig. 3). In this case the two pelves are situated in two sinuses. Although the two open into a common sinus medially, there is laterally a distinct separation into two parts. The ventral wall of the common sinus

presents two narrow but deep notches, one opposite each of the subdivisions. The ventral wall of the common sinus between the notches projects as far medially as the dorsal wall (fig. 3).

The inferior pelvis is somewhat larger than the superior. The cephalic end of its ureter is somewhat dilated just outside the sinus and passes gradually into the pelvis which represents a single major calyx subdivided into five minor calyces.

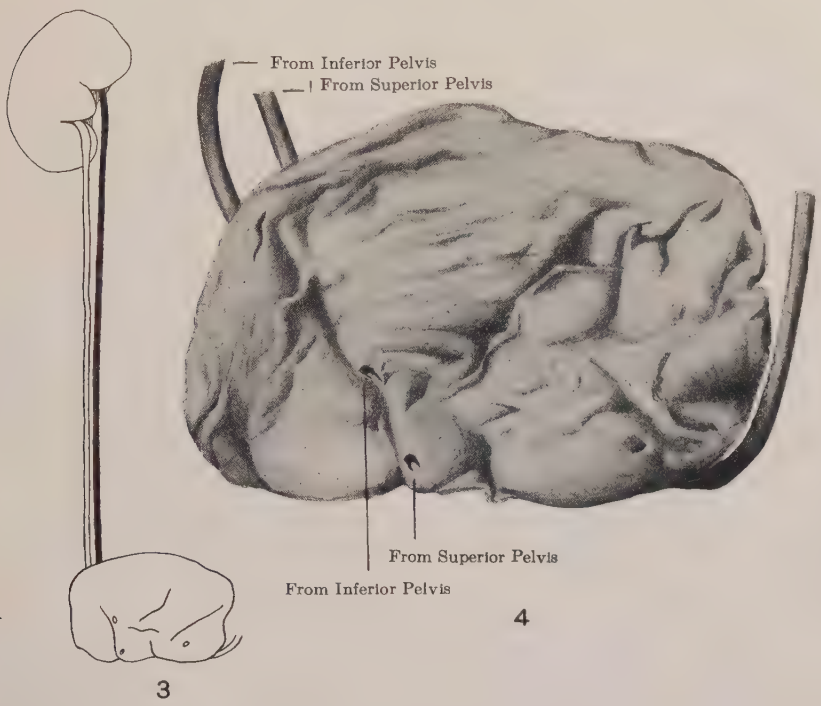


Fig. 3 (× ¼) Semidiagrammatic outline of case no. 2. Ventral view.
Fig. 4 (× 1) Drawing of the bladder of case no. 2 showing openings of the ureters.

The ureter from the superior pelvis, on the other hand, maintains a nearly uniform calibre until it passes rather abruptly into its pelvis. This also is single representing only one major calyx and divided into five minor calyces.

The neck of the bladder was cut away in removing the specimen from the body, so that it is not now possible to determine

the relations of the ureters to the internal urethral orifice. In spite of this the ureters were attached to the bladder walls in such a way that it is comparatively easy to tell what had been the relations of the ureters to one another before the specimen was removed from the body. The ureter from the superior pelvis opens into the bladder ventro-inferior as well as medial to the ureter from the inferior pelvis (fig. 4). The only question that might be in doubt from the specimen is the medio-lateral distance between the two openings. I believe that the specimen indicates that the opening of the ureter from the superior pelvis is but slightly medial to that from the inferior pelvis.

Although the whole bladder was not preserved, the appearance of the mucosa and muscle indicates that this is a moderately dilated bladder. The distances between the openings of the ureters are given in table 2.

The kidney is 8.4 cm. long and 5.5 cm. wide at its widest point. The surface is smooth except for the notches in the medial border opposite which the two arteries enter to supply the kidney. The main artery passes both ventral and dorsal to the pelves. The accessory artery, which is about one-third as large enters the most inferior part of the sinus and supplies the inferior part of the kidney ventral to the inferior pelvis. The medial ends of both arteries had been cut away so that now it is not possible to say whether the smaller artery connected with the main renal artery or directly with the aorta.

Although the left kidney was not preserved, the ureter on this side was cut at a considerable distance from the bladder so that the relations of its terminal end to the bladder are not disturbed. None of the generative organs were preserved so it is impossible to say whether there are any other anomalies of the genito-urinary system.

The third case is from subject number 242 of the Cornell University series, a white female about fifty-one years old who died of pulmonary tuberculosis. Two ureters arise from the left kidney (fig. 5). Laterally the kidney has two distinct sinuses, one for each pelvis. Medially these sinuses open into a common cavity, since the mass of kidney tissue separating them does not

come quite to the medial border. Moreover, the dorsal walls of the sinuses are distinctly shorter than the ventral. This is more marked inferiorly so that the inferior pelvis is quite outside the sinus as seen from the dorsal surface, but is covered by the ventral wall of the sinus so as not to be seen from this side.

5

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Fig. 5 (× ¼) Semidiagrammatic outline of case no. 3. Ventral view.
Fig. 6 (× 1) Drawing of the bladder of case no. 3 showing trigone and openings of the ureters.

The superior pelvis presents a single major calyx which is divided into two minor calyces. The ureter just outside of the sinus presents a slight dilatation and the dilatation of the major calyx is also so slight that it might almost be said that the ureter divided into two minor calyces without a pelvis.

The inferior pelvis is larger than the superior and drains about two-thirds of the kidney. It is divided into three major calyces. Of these the cephalic is subdivided into four minor calyces, the caudal into two minor calyces while the intermediate major calyx is not subdivided.

The ureter from the superior pelvis opens into the moderately contracted bladder, medial and somewhat ventro-inferior to the ureter from the inferior pelvis (fig. 6). From table 2 it will be seen that the orifice of the ureter from the inferior pelvis is but 2 mm. farther from the internal urethral orifice than the orifice of the ureter of the normal side, while the orifice of the ureter from the superior pelvis is 4 mm. nearer the internal urethral orifice than that of the normal side.

The left kidney is 9.4 cm. long and 4.1 cm. wide in its widest part. Its surface is smooth and the lateral border is marked by but one notch at about its middle. The hilum presents a notch on the anterior surface opposite the superior sinus and as already noted the posterior boundaries of the sinuses are deficient expecially inferiorly. The whole suggests that the embryonic rotation of the kidney had been carried so far that the hilum points more dorsally than usual. A single artery which arises from the aorta supplies this kidney. Its branches pass both dorsal and ventral to the pelves. A single vein drains the kidney and empties into the inferior vena cave.

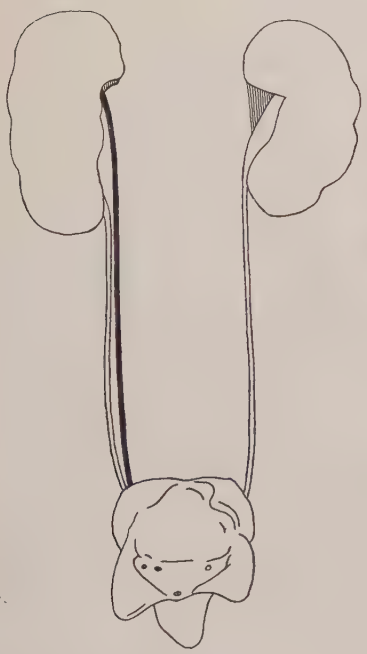
The right kidney is smaller measuring 7 cm. in length and 3.7 cm. in width. Its surface is smooth and shows only two slight notches on its lateral border. Its single pelvis is divided into two major calyces. It is supplied by but one artery and a single vein arises from it. None of the generative organs were retained.

The fourth case from subject number 258 of the Cornell University series, a white male aged sixty-eight years who died of endocarditis presented the double ureters on the right side (fig. 7). Each pelvis is situated in a separate sinus. These are completely isolated from one another by a broad mass of kidney tissue. The ventral and dorsal boundaries of the sinuses are nearly equally developed.

The superior pelvis is divided into two major calyces. These

are large and are not further subdivided but each receives a large irregular papilla formed by the junction of several renal pyramids.

The inferior pelvis is divided into two major calyces, the cephalic of these has four and the caudal three minor calyces. The superior pelvis is nearly as large as the inferior but the inferior drains slightly more than half the kidney.



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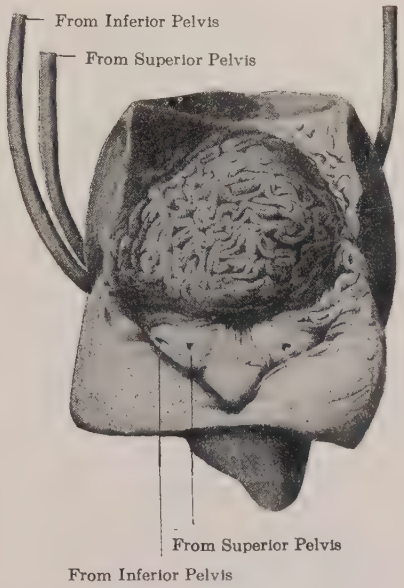

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Fig. 7 (× ¼) Semidiagrammatic outline of case no. 4. Ventral view.
Fig. 8 (× 1) Drawing of the bladder of case no. 4 showing trigone and openings of the ureters.

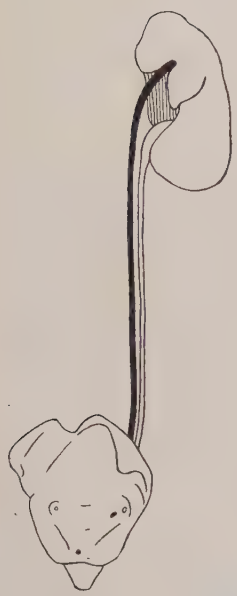
The ureter from the superior pelvis opens into the markedly contracted bladder medial and slightly ventro-inferior to the ureter from the inferior pelvis (fig. 8). As will be seen from table 2 the orifice of the ureter from the superior pelvis is 1 mm. nearer and that from the inferior pelvis 3 mm. farther from the internal urethral orifice than the orifice of the normal ureter.

The right kidney is 12 cm. long and 5.6 cm. wide in its widest part. Its surface is smooth and shows but slight indications of the embryonic lobulation. It is supplied by four main arteries of about equal size, all of which arise from the aorta. The superior of these supplies the kidney ventral to the pelves, most of its branches entering the superior sinus, two small branches, however, going to the inferior and two to the mass of tissue between the sinuses. The second artery which arises from the aorta 4 mm. inferior to the first enters the superior sinus and supplies the kidney dorsal to the superior pelvis. This artery arises from the aorta in common with another artery of about equal size which runs cephalically and to the right but was cut a short distance from the aorta. The third artery arises from the aorta 58 mm. inferior to the first. On the ventral surface of the aorta at this same level another artery arises which is probably the inferior mesenteric. The third artery enters the inferior sinus to supply the kidney dorsal to this pelvis. The fourth artery which arises from the aorta 83 mm. inferior to the first, and 8 mm. from the bifurcation of the aorta into common iliac arteries and at the level of origin of the last lumbar arteries, passes to the inferior edge of the inferior sinus and supplies the kidney both dorsal and ventral to the inferior pelvis. The third and fourth branches run dorsal to the ureters. Two veins lead from the kidney to the inferior vena cava. The larger one comes from both sinuses, the other much smaller from the inferior sinus only. They are both ventral to the ureters and pelves as they leave the kidney.

The left kidney measures 10.2 cm. in length and 6.5 cm. in width and its pelvis is rather indistinctly divided into two major calyces, the superior of these has two minor and the inferior five minor calyces. One artery supplies this kidney and a single vein returns the blood to the inferior vena cava.

The fifth specimen was sent to me by Dr. A. G. Pohlman and is from the anatomical laboratory of the Johns Hopkins University. It is from an adult male subject. I have no record of age or color. The duplication of the ureter is on the left side (fig. 9). The ventral walls of the sinuses are almost entirely lacking

but the deepest part of the sinuses are separated from one another by a septum of kidney tissue which is replaced medially by a well marked ridge on the dorsal wall of the sinus. The kidney measures 9.3 cm. in length and 4.5 cm. in width. It is supplied with but one artery and a single renal vein.



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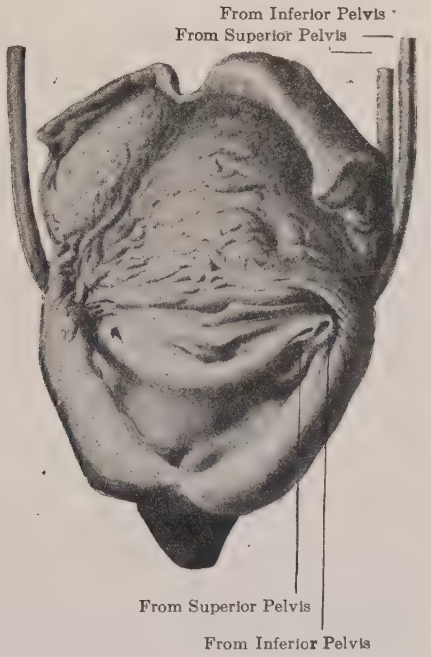

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Fig. 9 (× ¼) Semidiagrammatic outline of case no. 5. Ventral view.
Fig. 10 (× 1) Drawing of the bladder of case no. 5 showing trigone and openings of the ureters.

The superior pelvis represents but a single major calyx divided into two minor calyces.

The inferior pelvis, which is larger than the superior and drains

about two-thirds of the kidney, is divided into two major calyces, the cephalic of which has five minor and the caudal two minor calyces. Both pelves project beyond the sinus.

The ureter from the superior pelvis opens into the moderately contracted bladder medial as well as slightly ventro-inferior to the orifice of the ureter from the inferior pelvis (fig. 10). As will be seen from table 2, the orifices of both ureters from the left side are farther from the internal urethral orifice than the orifice of the normal ureter.

The right kidney was not sent with the specimen and none of the generative organs. The prostate had been trimmed away so close to the bladder that only the beginning of the prostatic urethra remained. This presented on its posterior wall a 3 mm. deep diverticulum which was closely attached to the bladder wall beneath the trigone.

In all of these specimens the dissection had progressed so far before they were discovered that it was not possible to make a careful record of the relations of the ureters to one another or to the other structures in the abdomen. The above descriptions are from the specimens after their removal from the body. It will be noted that all five cases are in adults. The age is known in three and is forty-five, fifty-one and sixty-eight years, respectively. The condition did not, so far as known, affect the health of the individual, as the cause of death where recorded was not connected with the kidneys.

The inferior pelvis is larger than the superior in every case, although the difference in size is not marked in cases nos. 2 and 4. The walls of the ureters were bound tightly together, this connection being especially close near the bladder. The external diameter of the two ureters is about equal in all cases. In all five cases the double ureters are completely separated throughout their course and open into the bladder by two separate orifices. That is, there is complete duplication.

In cases nos. 2, 3, 4, 5, the openings of the ureters from the superior pelves are ventro-inferior as well as more or less medial to the orifices of the ureters from the inferior pelves. That is, the ureter from the superior pelvis has the inferior orifice in the

bladder which is between the orifice of the ureter from the inferior pelvis and the internal orifice of the urethra. In case no. 1, although the orifice of the ureter from the superior pelvis like the preceding specimens is medial to the orifice of the ureter from the inferior pelvis it is on the other hand not ventro-inferior but is dorso-superior to the orifice of the ureter from the inferior pelvis. In all cases the orifices of the ureters from the superior pelves are nearer the median plane than the orifices of the ureters from the inferior pelves. In cases 1 and 2 they are but slightly, in cases nos. 3, 4, and 5 decidedly more medial.

Case no. 2 has the ureters 14 mm. apart, which is farther than in any other specimen. The bladder in this case was undoubtedly distended. In cases nos. 1 and 5, the orifices of the ureters are 3 mm. apart which is closer together than in any of the others. In both cases the bladder was moderately contracted. It will be noted also that in cases nos. 1 and 5 the orifices of both double ureters are farther from the internal urethral orifice than the orifice of the ureter from the normal side. In cases nos. 3 and 4 the orifices of the ureters from the superior pelves are nearer and the orifices of the ureters from the inferior pelves are farther from the internal urethral orifice than the orifices of the normal ureters.

There are indications of two sinuses in every case. In cases nos. 1 and 4 they are distinct throughout but in cases nos. 2, 3 and 5 they open medially into a common sinus so that from the surface these specimens appear to have a single sinus like a normal kidney. In case no. 5 the ventral wall of the common medial part of the sinuses was mostly lacking but there was a distinct ridge upon the dorsal wall of the sinus indicating the tendency to subdivision even outside the sinus proper.

I know of no statistics as to the frequency of complete double ureter. In an examination of 165 bodies in the anatomical laboratory at Cornell University, Ithaca, the four cases described above were the only cases of complete double ureter found. That is, in 2.42 per cent of these cases there was complete duplication of the ureters. This is not so very much less than the results

reported by Pohlman[1] in the embryo where he found two cases in an examination of "over 60 embryos" or 3.33 per cent. Both of his cases were males. Of the Cornell cases, three were males and one a female. Of the 165 cases examined 120 were male and 45 female. In the 120 male subjects complete double ureter was found to occur three times or in 2.5 per cent of the cases and in the 45 female subjects, it was found to occur in one or in 2.2 per cent of the cases. It would, therefore, appear to occur but slightly more often in the male than in the female. In regard to the side of the body, it was found three times on the right (1.81 per cent) and once on the left (0.60 per cent). It is not unlikely that in an examination of a larger number of bodies the percentages quoted above might be very much changed. As an example of this, I might say, that the examination of the intestinal tract of the same 165 bodies did not reveal the presence of Meckel's diverticulum in a single case although it has been found to occur in other series in 2 to 3 per cent of the cases. The above statistics would lead one to expect that complete double ureter on one side would be found by gynacologists and genito-urinary surgeons who are doing cystocopic work in about 2.5 per cent of their cases and that it would be more frequent on the right side.

It has been shown that the ureter arises in the embryo as a bud growing out from the lower end of the Wolffian duct at first dorsally and slightly medially and later shifting to a dorsal and slightly lateral position upon the duct. The blunt end of this bud enlarges and finally divides into a superior and an inferior limb which form the superior and inferior pelves of the kindey respectively. Later the ureter shifts to a distinctly lateral position upon the duct and the dorsal segment of the Wolffian duct between the ureter and the cloaca becomes shorter and shorter until finally we find the Wolffian duct and ureter opening into the cloaca separately but close together. These two openings now move gradually farther and farther apart, due to the growth of that portion of the wall of the cloaca which is situated between them.

[1] A. G. Pohlman. Abnormalities in the form of the kidney and ureter dependent upon the development of the renal bud. The Johns Hopkins Hospital Bulletin, vol. 16, no. 167.

Pohlman has advanced the theory that incomplete double ureter is caused by the division of the renal bud beginning too early and the division extending beyond the pelves into the segment belonging to the ureter so that the ureter remains permanently split into two, due to the exaggeration of the usual upper and lower pelves. Where more complete splitting of the renal bud occurs so as to be effected by the absorption of the segment of the Wolffian duct lying between the opening of the ureter and the cloaca, each ureter comes to have a separate opening in the cloaca, that is, complete double ureter is produced. Specimens nos. 2, 3, 4, and 5 seem to be explained very satisfactorily by this hypothesis. In cases such as these, it is evident that the ureter from the inferior pelvis must have been dorsal in the embryo and therefore closer than the ureter from the superior pelvis to the dorsal and lateral walls of the cloaca where the greatest development occurs. The ureter from the inferior pelvis would consequently be more affected by this expansion and would tend to move laterally and dorsally more than the other ureter. This is the condition which we find in the specimens mentioned above where the openings of the ureters from the inferior pelves are dorsal and lateral to those from the superior pelves. Case no. 1 is not fully explained by this hypothesis, for in this case the opening of the ureter from the inferior pelvis is ventral and lateral to that from the superior pelvis. Neither do I think that it is explained by the hypothesis advanced by Huntington[2] to explain one of his cases. He believes that in this case the additional ureter was derived from an additional bud which arose from the Wolffian duct distal to the main bud. In his case the superior pelvis presented the usual size and subdivisions of a normal kidney pelvis and represented therefore, the whole of the usual renal bud. This is not the condition in my case where the inferior pelvis is larger and moreover does not represent a complete kidney pelvis. For the same reason, Huntington's hypothesis does not apply to my other cases.

[2] Huntington, George S. The genetic interpretation and surgical significance of some variations of the genito urinary tract. Harvey Society Lectures, series 2, 1906–07.

A SELF-MADE NATURALIST[1]

GEORGE A. PIERSOL

Two-and-twenty years ago, a number of gentlemen, attending the Congress of American Physicians and Surgeons in Washington, decided that the time was ripe for banding together those especially interested in Anatomy. Consequently on September 17, 1888, the Association of American Anatomists was organized, its object, as formally set forth in the original constitution, being the "advancement of the anatomical sciences."

The choice of president of the new society was unhesitatingly made by the election of Professor Joseph Leidy, admittedly the most distinguished scientist of the country identified with anatomy. Dr. Leidy's interests in the study of nature were so broad that "Naturalist" is the only title that fittingly recognizes his extensive activities and vast knowledge concerning the natural sciences. As aptly expressed by one[2] of his biographers, "He was an excellent mineralogist and a botanist without claiming to be either, among the highest living authorities on comparative anatomy and zoölogy, one of the most distingushed helmintholo-gists, and the equal of any paleontologist at home or abroad."

It is, however, more particularly to the influence of the first president of this association as anatomist that I venture to invite your attention, for, notwithstanding the lengthening perspective, the illuminating rays of this influence still stream far along the road that anatomy in this country has journeyed to reach the recognized high position which it today enjoys.

An incident recorded by the late Dr. William Hunt, of Philadelphia, will serve as biographical note and at the same time

[1] Presidential Address, American Association of Anatomists, December 28, 1910.

[2] Henry C. Chapman: Memorial Address, Proceedings Acad. Nat. Scienc. of Phila., June 30, 1891.

will illustrate the directness, simplicity and gentleness, which were such impressive characteristics of the great naturalist. On the occasion of a popular lecture, Dr. Hunt, who was to present the speaker, remarked, that the introducer was less well known THAN he to be introduced. Whereupon Professor Leidy replied: "I will introduce myself!" and stepping to the platform said: "My name is Joseph Leidy, doctor of medicine. I was born in Philadelphia on the ninth of September, 1823, and have lived here ever since. My father was Philip Leidy, the hatter, on Third Street, above Vine. My mother was Catharine Mellick, but she died a few months after my birth. My father married her cousin, Christina Mellick, and she is the mother I have known, who was all in all to me, the one to whom I owe all that I am. At an early age I took great delight in natural history and in noting all natural objects. I have reason to think that I know a little of natural history, and a little of that little I propose to teach you tonight."

In order to appreciate the circumstances which were potent forces in shaping Dr. Leidy's career, a few facts concerning his early life should be noted, the more so since these were contributed by Dr. Leidy himself during a conversation in 1867 with Dr. Edward J. Nolan, of the Philadelphia Academy of Natural Sciences by whom they were recorded. "I was always what other boys called a 'queer boy,' never caring much to join in their sports, but anxious to see how plants and animals were made, as other boys were curious about the internal construction of their toys." The first opportunity to gratify this curiosity was afforded by the death of an old hen, whose body was opened, organs examined and skeleton preserved by the school boy. Nor were these early excursions into anatomy limited to the vertebrates. A visiting relative enlivened his letter home by a description of "Joe, sitting on the floor, looking at the insides of an earth-worm stretched upon a board." These incidents, trivial in themselves, exhibit the early development of that insatiable desire to understand natural phenomena and to explore the world of life around him—a passion which led him to read from nature's book wherever opened. Searching the fields and streams, young Leidy became

familiar with the local fauna and laid the foundations of the astonishing store of facts amassed by his own accurate observation.

Meanwhile, the problem of earning a living forced attention. The boy's unusual facility in using his pencil—a book of sketches of shells made when he was twelve still testifies to this ability—suggested to the father that the son might succeed as a sign-painter. The mother, with keener foresight and higher ambition, urged that he should study medicine and thereby enter a career that should supply not only a livelihood, but opportunities for congenial study. "Previous to this," as Dr. Leidy tells us, "I had become so much interested in the anatomy of worms, that I thought I should like to know something of the anatomy of man. So I induced my father to give me the money to procure a treatise on that subject."

When Leidy was seventeen, he began the study of medicine under Dr. James McClintock, who was then a private teacher of anatomy of some note. Here the young man spent a year in dissecting, before matriculating as a student of medicine. To quote Dr. Leidy's words: "I was so disgusted with the dissecting room that, after spending the first half day there, I went away and could not be induced to return for nearly six weeks, and I did not get entirely over the melancholy produced for a year. Then the desire to acquire information gradually overcame my repugnance; but so far was I from shaping my course for myself, that I never gave up the idea of sometime forsaking the dissecting room, until I was elected to my present position as professor of anatomy."

After entering the Medical School of the University of Pennsylvania, in 1841, Leidy continued his anatomical studies under the immediate supervision of Dr. Paul B. Goddard, then Demonstrator of Anatomy, who not only afforded the young student unusual opportunities for dissection, but also gave him his first instruction in the use of the microscope—an accomplishment in those days far from common. Three years later, in 1844, he received the degree of doctor of medicine, his thesis, on "The Comparative Anatomy of the Eye of Vertebrated Animals," foreshadowing his growing interest in the broader phases of anatomical science.

On graduating, Dr. Leidy became assistant in the dissecting room and aided Dr. Goddard, who was also prosector to the professor of anatomy, in making the dissections for the lecture-table. The expertness of the young anatomist so impressed Professor Horner, that, on the resignation of Dr. Goddard the ensuing year, he appointed Dr. Leidy his prosector.

The necessity of earning a livelihood induced Dr. Leidy to open an office and assay the practice of medicine. His success was far from encouraging and the demands upon his professional skill were few. The enforced leisure of office hours, however, was devoted to congenial studies in natural history, and Dr. Leidy himself relates, that on one occasion he was so deeply absorbed in his office in investigating the anatomy of a worm, that he quite forgot having been called to an obstetric case, which he had engaged to attend. After two years of indifferent success, realizing that teaching offered a surer means of support, he permanently abandoned the practice of medicine.

In 1846, Dr. Leidy temporarily severed his connection with the University of Pennsylvania to accept the position of demonstrator of anatomy in the Franklin Medical College, in which institution, just established, his friend and preceptor, Dr. Goddard, occupied the chair of anatomy. This new position afforded the opportunity for his first course of lectures on anatomy, before a class of ten students. After a year, however, he relinquished the post and resumed his prosectorship under Horner, additionally conducting an excellent private course on human anatomy. The following year, on his return from a visit to Europe as the companion and guest of Professor Horner, Dr. Leidy delivered a course of lectures on microscopical anatomy and inaugurated an extramural course on physiology. The latter venture was so successful and popular, that Dr. Leidy was seriously regarded as the probable next incumbent of the chair of physiology in the University of Pennsylvania following an anticipated, but never consummated, readjustment of the professional staff.

About this time Dr. Leidy's services were sought by Dr. George B. Wood, the newly elected professor of medicine, to assist in forming the notable collection of preparations and models, illus-

trating pathlogical changes, which marked a new era in objective teaching in this country. On returning from a second visit abroad, this time in company with Dr. Wood, Dr. Leidy became assistant to the professor of medicine, while still retaining the position of prosector, and in this way insured himself a definite, although most modest, means of support. A keen interest in pathology being thus aroused, he served as hospital pathologist, established experimentally the possibility of successfully transplanting into animals cancerous growths and translated Gluge's *Atlas of Pathological Histology*. In this connection it may be added that later, during the Civil War, Dr. Liedy held an appointment as surgeon and performed numerous autopsies, the reports on which were incorporated in the *Medical and Surgical History of the War*, while the preparations illustrating these reports were deposited in the Army Medical Museum at Washington. At the same time, be it parenthetically noted, he lost no opportunity of securing desirable additions to the anatomical collections of the University.

Meanwhile, although diligently pursuing human anatomy and, as we have just seen, entering with zeal the domain of pathology, the young physician had never ceased to devote to natural history whatever of leisure remained after the demands of his medical work—the more immediate "business" of his life—had been met. Continuing to investigate whatever came within his reach, Leidy acquired a familarity with animals and plants such as accurate personal observation alone could supply. Knowing these tastes, as well as his ability as an artist, Dr. Goddard was led to recommend Leidy, while still a medical student, to Dr. Amos Binney, of Boston, as one well qualified to make dissections and drawings illustrating the anatomy of the land snails, for an exhaustive monograph then in preparation. The submitted examples of his work were so satisfactory, that Leidy was engaged to study the anatomy of the snails, he to receive five dollars for the dissection and drawing of each.

Directed by these circumstances, it was not long before the young naturalist's sharp observation led to discoveries in molluscan anatomy worthy of record. Dr. Leidy's first formal contribution to science was a paper on the anatomy of *Littorina angu-*

lifera (a form of winkle), submitted to the Boston Society of Natural History, July 16, 1845, while his first communication to to the Academy of Natural Sciences of Philadelphia related to fossil mollusks. It may be noted in passing, that his election to membership in the Philadelphia Academy, July 29, 1845, had been anticipated by that in the Boston Society by a few weeks. Although the mollusca commanded his particular attention for sometime, as evidenced by several papers during 1846 and 1847, the claims of other forms, both higher and lower, were not ignored, for Dr. Leidy's interest in zoölogy was so broad, that whatever of novelty to him came under his notice was subjected to searching scrutiny.

Parasites already engaged his attention. In 1846, one morning while breakfasting, he noticed peculiar specks in the ham which he was about to eat. Upon microscopic examination, he recognized these specks as being encysted *trichina spiralis*. This observation, recorded in the proceedings of the Academy of Natural Sciences, directly led to the subsequent discovery by Leuckart that trichinosis in man is due to the eating of raw or insufficiently cooked trichinous pork. A striking example, indeed, of the possible far-reaching influence of the observations of the scientist on questions of profound import affecting the welfare, as well as economic relations, of nations!

It must not be supposed, however, that these investigations of the lower forms diverted Dr. Leidy's active interest from the anatomy of the vertebrates. Every opportunity of examining the less familiar animals was utilized. Such opportunities, however, were rare and afforded chiefly by the death of an animal belonging to some itinerant menagerie while exhibiting in the city. Communications concerning the intercostal nerves of the boa constrictor and the abdominal viscera of the sloth, including the description and figuring of the sloth embryo, were early results of such opportunities.

Dominated by the desire to see things for himself and as they actually are, Dr. Leidy profited by the repeated dissections of the human body which he had occasion to make while fulfilling his duties as prosector. Moreover, he was continually comparing

the results of his observations on other animals with the details presented by man. In this way, after dissecting the larynx in other mammals, he was impressed by the inaccuracy of the descriptions of the structures concerned in the production of voice. His dissections clearly demonstrated that the then current "chordae vocales," as such, did not exist, and that the so-called thyro-arytenoid ligaments were the modified lateral borders of the crico-thyroid membrane, which latter was a much more extensive sheet than heretofore recognized. Likewise, the arrangement and relations of the thryo-arytenoideus, as well as of the thryo-epigottidean and aryteno-epiglottidian muscles, were described with greater accuracy. In this paper occurs the following: "Not being partial to any particular theory in regard to the production of voice, I present merely the unvarnished facts as existing in my dissections." This expression early emphasized a dominating characteristic of Dr. Leidy's work, for throughout his long and fruitful scientific career, he seldom departed from his purpose to record facts and to abstain from speculation.

In 1847 occurred an incident, that was to influence profoundly Dr. Leidy's subsequent fields of activity, namely, the receipt of some fossils from Nebraska, which had been collected by persons connected with the western fur-trade and sent east to friends as curiosities. These specimens Dr. Leidy examined and reported to the Academy of Natural Sciences in short communications on the fossil horse of America and on a new fossil ruminant (*Pœbrotherum*), with camel-like characteristics.

Two years later the first considerable collection of vertebrate fossils from the "Bad Lands" of Nebraska were placed at Dr. Leidy's disposal. This material furnished a rich yield of important discoveries concerning the extinct fauna of this continent and formed the basis of a comprehensive account of fossil remains published in 1852. Professor Baird of the Smithsonian Institution became deeply interested in these new and promising lines of investigation. It was indeed, as Dr. Leidy himself tells us, the direct appeal of Professor Baird that induced him to take up seriously the study of paleontology. "I thought," he confesses, "I would soon exhaust the supply of specimens in the Academy

and would then return to pathology. But the specimens continued to pour in, new material was discovered and the supply has not yet been exhausted." In this way, so largely accidental, began his identification with American paleontology, an association which resulted in discoveries of the greatest moment in supporting the doctrine of Organic Evolution and in placing Leidy in the foremost rank of paleontologists.

Coincidentaly with his entrance into the field of paleontology, Dr. Leidy was busy with his scalpel and his Oberhaeuser microscope. His keen interest in structural anatomy was, no doubt, stimulated by his close association with Professor Horner, who was an histologist of distinction. In 1848, appeared Leidy's papers, "On the Development of the Purkinjean Corpuscle of Bone," "On the Intimate Structure of Articular Cartilage," "On the Arrangement of the Areolar Sheath of Muscular Fasciculi and its Relation to the tendon," and "Researches into the Comparative Structure of the Liver." The last named paper recorded observations on the hepatic tissues of twenty-six animals, which included such diverse forms as the centiped, tumblebug, katydid, house-fly, cray fish, snail and the representatives of the fishes, amphibians, birds and mammals. While, so far as concerning the human liver, in the main corroborating the classic description given by Kierman fifteen years before, the importance of the paper under notice lay in establishing the fundamental correspondence of the hepatic tissues of many orders of animals, as cæcal outgrowths lined with glandular epithelium. The contribution concerning the structure of articular cartilage is of interest as calling attention to the fibrillar basis of the matrix.

In the autumn of 1848, appeared the fifth edition of Jones Quain's *Human Anatomy*, edited by Richard Quain and William Sharpey. The book, as recast by its editors, was an important addition to medical literature, representing, as it did, the most complete and up-to-date treatise on the anatomy of man in the English language. The American medical student of that day depended chiefly upon "Wilson," then in its fourth American edition by Goddard, and upon "Horner," for "Gray" did not exist until ten years later. While very occasionally reference was

had to Cruveilhier or to Arnold or Hyrtl by the student in search of fuller details, the convenience of an adequate work in English was so evident, that an American edition of the new "Quain" seemed called for. Dr. Leidy assumed the duties of editor and six months after its appearance in England the work was published in Philadelphia. The American editor's labor was far from perfunctory, but, on the contrary, embraced many desirable additions, both to text and illustrations; some of these additions were based upon his own observations and thus contributed to the originality of the work. The systematic discussion of the development and ossification of the individual bones was included in Quain for the first time in the fifth edition. The results of Dr. Leidy's investigations on the intermaxillary bone of the human foetus were incorporated and materially supplemented, by two figures of the bone and a careful description, the presentation given by Leuckart nine years before. Dr. Leidy's ability as an histologist enabled him to add numerous notes and figures concerning microscopical details, while his knowledge of the body gained by direct observation, suggested betterments or modifications in the portrayal of macroscopic features. The publication of the American edition of Quain, therefore, strengthened the growing reputation of Dr. Leidy's as a young anatomist of unusual promise.

Reference has been made to the accidental manner in which Dr. Leidy became interested in paleontology at the time when he was industriously advancing his relations with medical education as prosector and pathologist. Professor Baird was so impressed with the importance of the discoveries wrested by the young anatomist from the Nebraskan fossils, that he arranged for securing additional specimens from the "Mauvises Terres" under the auspices of the Smithsonian Institution. This new collection he placed in the hands of Dr. Leidy, as the American anatomist most competent to do it justice. That this estimate was well founded, was amply demonstrated by the preparation during 1852 of the Smithsonian contribution, "The Ancient Fauna of Nebraska," the first of Dr. Leidy's epoch-making memoirs revealing the unsuspected richness of the extinct vertebrate fauna of this continent.

Once opened to search, the "Bad Lands," became the collecting grounds of repeated expeditions sent out to gather fossils. These collections, entire or in part, were submitted to Dr. Leidy. The duty of improving these unexcelled apportunities for adding extensively to the knowledge of the North American fauna was too imperative to be disregarded by one so well equipped to till these newer fields of zoölogical investigation. Dr. Leidy therefore accepted the obligation and continued his paleontological studies. In following this decision he was supported, perhaps even influenced, by the encouragement of those who appreciated his particular fitness for the task in possessing a remarkable knowledge of osteology, an unusually keen and accurate observation, a surprising memory for form and a purpose to record faithfully and impartially, unbiased by theory and speculation.

Years after, in a letter to Professor Flower acknowledging the award of the Lyell Medal by the Geological Society of London, Dr. Leidy writes: "I must add that I feel as if Sir Charles Lyell himself were expressing satisfaction in consideration of my having complied with his wish when thirty years ago, in my own home here, he said he hoped I would devote my time to Paleontology instead of Medicine."

Sustaining to intellectual life as were the stony fossils of the far West, in those early days of American Science they offered but a meagre source for daily bread. It was, therefore, not only with the satisfaction of recognized merit, but also with the relief of an assured livelihood, that Dr. Leidy in 1853 accepted the chair of anatomy in the University of Pennsylvania. The failing health of his predecessor, Dr. William E. Horner, had given Dr. Leidy opportunities to demonstrate his ability as a teacher. This qualification, together with his already high reputation as a naturalist, won for Dr. Leidy the professorship notwithstanding rival claims backed by wealth and social influence.

Although the rich collections of the deservedly noted Wistar and Horner Museum placed at the disposal of the new professor adequate means of teaching anatomy, Dr. Leidy devoted many hours to making additional preparations and drawings for his course, and supplemented his demonstrations of the human body

with specimens from other animals, in this way often emphasizing the significance and broader understanding of the anatomical details found in man.

From this time Professor Leidy consistently recognized the teaching of human anatomy as his vocation, never permitting the fascinations of his other scientific studies to conflict with the conscientious discharge of the duties connected with his academic position. The simplicity and straightforwardness of the teacher's nature were reflected in his instruction, in which he ever strove to simplify and to divest of unnecessary complexity the descriptions of the body. To this end and in response to urgent solicitation, Dr. Leidy prepared *An Elementary Treatise on Human Anatomy*, which appeared in 1861 and at once found favor with the student confronted with the conventional maze of anatomical detail. No book ever fulfilled its avowed purpose better. Intended as an introduction to human anatomy, the attempt was made to smooth the tyro's path by eliminating from the text all synonyms and retaining only such names, one for each structure, as seemed from long general usage or descriptive character best suited for the purpose. Further, the adopted terms were used, so far as permissible, in the anglisized form. Numerous footnotes afforded the reader at a glance a suggestive survey of the other names which had been or still were applied to the structure under discussion. Even today, this copious synonymy often conveniently supplies information concerning anatomical terms long since obsolete. The avoidance of proper names and the curtailment of terms by dropping unnecessary words were other timely reforms offered by Dr. Leidy's nomenclature. This attempt to relieve anatomy of a needlessly cumbersome and confused terminology met with little encouragement; the experiment, however, will endure as a tribute to the love of simplicity and directness, which were such conspicuous characteristics of the great anatomist. The preparation of a second edition of his text-book, which, entirely rewritten and considerably amplified, appeared in 1889, gave Dr. Leidy the opportunity to incorporate the results of his long years of observation on the human body. Thus the account of the development of the temporal bone was

based on studies by which, among other points, it was shown that Professor Huxley's epiotic center was not entitled to be regarded as an independent one, but only as a continuous out growth from the opisithotic. While shown often by a single sentence, or even phrase, many evidences of the author's close study and broad comprehension of the human body are discernible to the appreciative reader. The second edition of his text-book appeared only two years before Dr. Leidy's death in 1891 and was the last of his formal contributions to human anatomy.

Twenty years before, that is in 1871, Dr. Leidy extended his professorial duties by accepting the chair of Natural History in Swarthmore College. This congenial position he held until 1884, when upon the establishment of the Biological School of the University of Pennsylvania, he became the director of that institution and professor of Zoölogy and Comparative Anatomy in the university, thenceforth serving his alma mater in a double teaching capacity.

Pausing merely to mention some of Leidy's more notable achievements, we must return to those first triumphs in paleontology in the early fifties. The completion of "The Ancient Fauna of Nebraska" was followed in close succession by communications recording the discovery of many extinct animals, the existence on this continent of some of which had never been suspected. An important memoir on the "Extinct Sloth Tribe of North America" was followed by others pertaining to remarkable fossil fishes and Cretaceous reptiles, among the latter the huge *Hadrosaurus*, 28 feet in length.

In 1869 appeared "The Extinct Mammalian Fauna of Nebraska and Dakota," an elaborate monograph of nearly 500 quarto pages, with 30 plates, embodying the results of Dr. Leidy's long series of brilliant investigations on the western fossils. A most valuable feature of this publication is the appended "Synopsis of Extinct Mammalia of North America," in which are systematically arranged the representatives of the orders, so far as then known, together with the name of the discoverer of each and the authoritative references. An indication of Dr. Leidy's wonderful productivity is given by the fact, that no less than 176 new

species named in this synopsis were described and added by him to the list of extinct mammals of this continent. The last of Dr. Leidy's great memoirs concerning western fossils, "Contributions to the Extinct Vertebrate Fauna of the Western Territories," appeared five years later, in 1873, and was regarded by the author, at the time, as his final paleontological contribution. This conclusion, however, gave way when, some years later, new material from the southern states offered new conquests and supplied the basis of an important memoir on the vertebrate remains from the Phosphate Beds of South Carolina. Indeed, material from Florida engaged the attention of the naturalist at the time of his death, the descriptions of interesting finds of mastodon, rhinoceros, hippotherium and procamelus being among the most important of his posthumous papers. The fact, that more than one-third of the 599 titles included in Dr. Leidy's bibliography pertain to extinct forms, shows the large share of his attention claimed by paleontology, while the exactness of his observations and the importance of his discoveries placed him for all time among the greatest contributors to this field of knowledge.

Notwithstanding this impressive fertility, Dr. Leidy found time for extensive investigations along other lines. His early interest in worms and parasites never waned and from time to time these forms were the subjects of study, discovery and record. His numerous and important contributions won for Dr. Leidy a high reputation as a parasitologist and doubtful specimens from all parts of the land were submitted to him as the final authority in this country. Mention must be made of the unique and beautifully illustrated memoir, "A Flora and Fauna within Living Animals," published as early as 1853, by which was demonstrated in a most striking manner the fact that the intestinal mucosa of many animals, such as cock-roaches and centipedes, is the usual abode of a great variety of parasitic plants and animals. In passing it may be noted, that forty years ago Dr. Leidy uttered a warning against the danger of flies as a means of transmitting disease.

With the completion of his labors on the extinct fauna of the western territories, in 1873, Dr. Leidy eagerly turned to the study of the microscopic forms of animal life. Although always at-

tracted to these humbler members of the zoölogical family, the necessary leisure for their systematic study had heretofore been denied him by the claims of paleontology. A considerable part of his time for the next few years was devoted to the life-histories of microscopic animals, and some of us recall the unmistakable pleasure with which the great naturalist often exhibited to an appreciative visitor the surpassing beauty of the minute organisms upon the stage of his microscope. As the result of these patient although congenial investigations, in 1879 appeared the "Fresh-water Rhizopods of North America." This report was based upon the examination of not merely the more or less local species, but of the rhizopods "as they occur in all fresh waters of the country, from the Atlantic board to an altitude of 10,000 feet in the Rocky Mountains." The originals of the many hundreds of figures are all by Dr. Leidy's hand. While the chromo-lithographic plates illustrating the publication are excellent, they fall far short of the beauty and delicacy of the author's drawings.

In the concluding pages of the monograph occurs the following: "The study of Natural History in the leisure of my life, since I was fourteen years of age, has been to me a constant source of happiness, and my experience of it is such that, independent of its higher merits, I warmly recommend it as a pastime, than which, I believe, no other can excell it. At the same time, in observing the modes of life of those around me, it has been a matter of unceasing regret that so few, so very few, people give attention to intellectual pursuits of any kind. In the incessant and necessary struggle for bread, we repeatedly hear the expression, that 'Man shall not live by bread alone,' and yet it remains unappreciated by the mass of even so-called enlightened humanity."

Leidy's attitude towards Organic Evolution can be confidently foretold from the character of his scientific labors, for how could anything less than enthusiastic support be the attitude of one who had added so much to the knowledge concerning the fauna of past ages. It is interesting to note that in his "Flora and Fauna within Living Animals," which was written in 1851, although not published until two years later, occur the following reflections. "The study of the earth's crust teaches us that very many species

of plants and animals became extinct at successive periods, while other races originated to occupy their places. This probably was the result in, many cases, of a change in exterior conditions incompatible with the life of certain species and favorable to the primitive production of others. . . . Living beings did not exist upon earth prior to their indespensible conditions of action, but whenever these have been brought into operation concomitantly, the former originated." These speculations, written eight years before the appearance of the *Origin of Species*, indicate how Leidy and, no doubt other naturalists as well, had glimpsed the truths of Evolution. The effect of Darwin's epoch-making work upon Dr. Leidy was, to quote his own words, "as though I had hitherto groped almost in the darkness and that all of a sudden a meteor flashed upon the skies." Leidy and Asa Gray were the first in this country to appreciate the full significance of the theory of Organic Evolution and to expound its teaching.

Replying to Dr. Leidy's congratulations on the publication of the *Origin of Species*, Mr. Darwin wrote: "Most paleontologists (with some few good exceptions) entirely despise my work; consequently approbation from you has gratified me much. All the older geologists (with the one exception of Lyell, whom I look at as a host in himself) are even more vehement against the modification of species than are even the paleontologists. . . . Your sentence, that you have some interesting facts in support of the doctrine of selection, has delighted one even more than the rest of your note." This promise of support was amply fulfilled by the facts revealed by Dr. Leidy's brilliant discoveries in paleontology.

Such, as briefly outlined, being the scientific achievements of the subject of this sketch, we may ask: "In what way and to what extent is anatomy indebted to Joseph Leidy?" Notwithstanding the fact, that his formal contributions to Human Anatomy were few and written, for the most part, during his earlier years, his influence in winning for anatomy in this country a recognition as a Science, independent of its practical applications, was profound. That anatomy should be satisfactorily represented by one whose interests were so divorced from medicine, was im-

pressive at a period when little sympathy was accorded that which lacked evident utility. The reputation and growing eminence of the man of science commanded respectful attention, and little by little the importance of his repeated expositions as to man's place in nature and the morphological significance of the details of the human body was admitted by a widening circle within the medical profession. This leaven was carried, aften unconsicously, far and wide by thousands. Who, among us, whose privilege it was to sit before Leidy—so great and yet so simple—will forget the impressions left by his earnest appeals for the great biological truths? To most, it was the first glimpse of a more adequate conception of nature, and from that lecture-hall went many a man with the old fetters of thought forever shattered!

As a teacher, Dr. Leidy was clear, simple and concise and ever ready to impress the details of the human body by apt references drawn from his vast knowledge of comparative anatomy. Always glad to share his information, whether to explain or to correct and assist, be the applicant student or colleague, Dr. Leidy's blunt love of the truth brought speedy discomforture to pretense. False imagery, whether in science or in art, to him was intolerable. That the traditional angel, as an impossible six-limbed vertebrate, should have so long survived, always excited Dr. Leidy's wonder.

The two decades just elapsing since Dr. Leidy's death in 1891, have already weakened the impression made by his personality; not many more years, and the deep and affectionate regard of all who knew him will be replaced by the impersonal respect due one of the great pioneers of American science.

Let our young anatomists, who are so enthusiastically and successfully pushing out along the various lines of work, neither forget the achievements nor underestimate the services of these pioneers, for to the influence of these men they owe the opportunities for training and accomplishment which this country today offers. To furnish an inspiring example of untiring industry and devotion to research, to set a high ideal of unswerving loyalty to accuracy and truth, to aid in creating a respect and an appreciation for anatomy as a science—these are among the services to American Anatomy rendered by the first president of this association.

PROCEEDINGS OF THE AMERICAN ASSOCIATION OF ANATOMISTS

TWENTY-SIXTH SESSION

The twenty-sixth session of the American Association of Anatomists was held at Brussels, Belgium, August 7 to 11, 1910, in affiliation with the Anatomical Society of Great Britain and Ireland, the Anatomische Gesellschaft, the Association des Anatomistes, and the Unione Zoologica Italiana, the joint meeting of these associations constituting the Second International Congress of Anatomy.

The following members of the American Association of Anatomists were in attendance at the congress:

William H. F. Addison, *University of Pennsylvania.*
Charles R. Essick, *Johns Hopkins University.*
Herbert M. Evans, *Johns Hopkins University.*
William A. Hilton, *Cornell University.*
G. Carl Huber, *University of Michigan.*
George S. Huntington, *Columbia University.*
Harvey E. Jordan, *University of Virginia.*
Thomas G. Lee, *University of Minnesota.*
Charles F. W. McClure, *Princeton University.*
Caroline McGill, *University of Missouri.*
Burton D. Myers, *Indiana University.*
Charles S. Minot, *Harvard University .*
George A. Piersol, *University of Pennsylvania.*
George L. Streeter, *University of Michigan.*
John Warren, *Harvard University.*
Leonard W. Williams, *Harvard University.*

At a meeting of the general committee, consisting of the presidents and secretaries of the several associations constituting the congress, held August 7th, 4:30 p.m., in the Anatomical Institute of the University of Brussels, special consideration was given to the program. After discussion, it was decided that the papers and demonstrations listed in the provisional program, under the

heads of each of the several associations be arranged for each daily session, by selecting in rotation, papers and demonstrations from each of the several association programs.

The morning sessions, from 9.00 to 1:00 p.m., held in the Physical lecture room of the University, were devoted to the reading of papers. The afternoon sessions, from 3:00 to 6:00 p.m., held at the Anatomical Institute, were devoted to demonstrations. At the morning sessions, the presidents of the five associations participating in the congress presided in rotation.

At the Wednesday morning session, Professor Charles S. Minot presented as delegated on behalf of the Association of American Anatomists a recommendation for the appointment of an International committee to revise embryological nomenclature and prepare a list of standard terms. After discussion this recommendation was adopted by the Congress and a committee constituted as follows appointed: Professors Keibel, Minot, Romiti, Bryce, Nicola, Hubrecht, Brachet, Eternod, Hill, with Professor Mall as general secretary of this committee.

The following papers and demonstrations were listed by members of the American Association of Anatomists and presented at this Second International Congress of Anatomy, with exceptions as noted.

A. PAPERS.

Charles S. Minot: Zur Nomenklatur und Morphologie der Blutkörperchen.
Leo Loeb and W. H. F. Addison: Experimental study of the growth of the skin of the Guinea pig and pigeon.
Leonard W. Williams: The somites of the chick.
Adolf Meyer: Observations on the optic thalamus, together with a demonstration of some glass models of this region. Read by title.
George S. Huntington: Beiträge zur Entwickelungsgeschichte des lymphatischen Systems der Säuger—illustrated by lantern slides.
Chas. F. W. McClure: The extra-intimal theory and the development of the mesenteric lymphatics in the domestic cat.
Chas. F. Silvester: On the presence of permanent lymphatico-venous communications in an adult South-American monkey at the level of the renal vein. (Presented by Prof. McClure.)
Thomas G. Lee: The implantation stages in various North-American rodents (with lantern slides).
Robert Bennet Bean: The ear as a morphological factor in racial anatomy (with lantern slides). Read by title.
G. Carl Huber: The morphology of the renal tubule of vertebrates (with lantern slides).

B. DEMONSTRATIONS

George L. Streeter: Demonstration of four models showing the development of the corpus callosum in the human embryo.

George S. Huntington: Demonstrations of lymphatic injections and reconstructions. Adult and embryos.

Demonstration of serial sections showing development of the main systemic vessels in the embryo of a cat.

George S. Huntington and Charles F. W. McClure: Demonstration of models illustrating the development of the jugular lymph-sac in the domestic cat (Felis domestica).

Chas. F. W. McClure: Demonstrations of serial sections showing development of the mesenteric lymphatics of the domestic cat.

Chas. F. Silvester: Demonstration of lymphatico-venous communications, at level of the renal veins in an adult South-American monkey. (Presented by Prof. McClure.)

Thomas G. Lee: Demonstration of microscopic slides showing implantation stages in North-American rodents.

G. Carl Huber: Demonstration of celluloid corrosions of the duct system and blood vessels of the kidneys of certain vertebrates.

G. Carl Huber,
Secretary-Treasurer.

PROCEEDINGS OF THE AMERICAN ASSOCIATION OF ANATOMISTS

TWENTY-SEVENTH SESSION

In Stimson Hall, Cornell University, Ithaca, New York, December 28, 29 and 30, 1910

WEDNESDAY, DECEMBER 28, 10:15 A.M., TO 1:00 P.M.

The twenty-seventh session was called to order at 10:15 A.M. by President George A. Piersol, who appointed the following committees: *Committee on Nominations;* Milton J. Greenman, *chairman;* George L. Streeter.

Auditing Committee; Robert J. Terry, *chairman;* Frederic T. Lewis.

Address of President George A. Piersol, University of Pennsylvania, "A Self-made Naturalist."

The following papers were presented:

BURT G. WILDER, *Cornell University.* The fissures of a half-size cerebrum. Illustrated by specimens, photographs and diagrams.

GEORGE S. HUNTINGTON, *Columbia University, New York City.* Development of the lymphatic system in reptiles. Lantern.

CLARENCE M. JACKSON, *University of Missouri.* The relative growth of the various organs in the white rat.

CLARENCE M. JACKSON, FOR L. G. LOWREY, *University of Missouri.* The prenatal growth of the various organs in the pig.

FREDERIC T. LEWIS. *Harvard University.* Some anomalies of the digestive tract in young human embryos.

SUSANNA P. GAGE, *Ithaca, New York.* The pair of intercerebral sacs as the origin of the fascia dentata in the human embryo. Lantern.

GEORGE E. COGHILL, *Denison University.* On the relation of certain commissures to the development of somatic movements of amphibian embryos. Read by title.

2:00 to 5:30 p.m. Demonstrations. (See announcement of demonstrations.)

8:30 p.m. Smoker, at the Ithaca Hotel, in conjunction with the American Society of Zoölogists and American Society of Naturalists.

THURSDAY, DECEMBER 29, 9:00 A.M. TO 1:00 P.M. SESSION FOR THE READING OF PAPERS, PRESIDENT GEORGE A. PIERSOL PRESIDING.

WILLIAM A. HILTON, *Cornell University.* The origin of the vitelline circulation and the transformation of some of the early vessels.

JEREMIAH S. FERGUSON, *Cornell University Medical School, New York City.* The reticulum of lymphatic glands.

WILLIAM H. F. ADDISON, *University of Pennsylvania.* The post-natal development of the cortical layers, and of the Purkinje cells, in the cerebellum of the albino rat.

SIMON H. GAGE, *Cornell University.* The structure and persistence of the notochord of the lamprey.

MONTROSE T. BURROWS, *Rockefeller Institute.* The growth of tissue of the chick embryo outside of the body, with especial reference to the nervous system.

H. VON W. SCHULTE, *Columbia University, New York City.* (a) The amniote homologies of the derivatives of the sulcus buccalis. (b) A note on the development of salivary glands in the human embryo. Lantern.

ELIOT R. CLARK, *Johns Hopkins University.* Further observations on living, growing lymphatics in the tail of the frog larva: their relation to mesenchyme cells.

FLORENCE R. SABIN, *Johns Hopkins University.* The thoracic duct in the pig.

ADAM M. MILLER, *Columbia University, New York City.* The development of the jugular lymphsacs in birds. Lantern.

FREDERICK TILNEY, *Columbia University, New York City.* The development of the axial venous and lymphatic systems in Tragulus memimna. Lantern.

FRANKLIN P. MALL, *Johns Hopkins University.* The arrangement of the muscle fasciculi in the ventricle of the human heart. Read by title.

ULRIC DAHLGREN, *Princeton University.* The structural changes during the contraction of mollusk muscle. Read by title.

HENRY H. DONALDSON. *Wistar Institute of Anatomy.* On the regular seasonal changes in the relative weight of the central nervous system of the leopard frog.

GEORGE L. STREETER, *University of Michigan.* (a) The volumetric analysis of the brain of the opossum. (b) The use of the expansion tank in the preservation of anatomical material. Lantern.

LEONARD W. WILLIAMS, *Harvard University.* The distribution of the third anterior thoracic nerve in the guinea pig.

THURSDAY, DECEMBER 29, 2:40 P.M. BUSINESS MEETING.

On motion of the Secretary the minutes of the twenty-fifth session were approved, as printed in the *Anatomical Record,* Vol. 4, No. 2, pages 93 to 102. On motion the minutes of the twenty-sixth session were approved as read.

The Treasurer made the following report for the year 1910:

Total Receipts for 1910, including balance in the Farmers and Mechanics Bank, Ann Arbor, Michigan, on December 23, 1909		$1713.41
Expenditures for 1910:		
Expenses of the Secretary, Boston meeting, 1909	$46.89	
Smoker, Boston meeting	13.00	
Postage	30.00	
Printing, typewriting, envelopes	38.26	
Association's share of general printing and services, International Congress, Brussels	6.28	
To 331 subscriptions to Vol. 10 of *American Journal of Anatomy* and Vol. 4, *Anatomical Record* @$4.50	1399.50	
Total	$1533.93	1533.93
Balance on hand Dec. 23, 1910, deposited in the Farmers and Mechanics Bank, Ann Arbor, Michigan		$ 179.48

Robert J. Terry reported for the Auditing Committee as follows: "We have examined the accounts of G. Carl Huber, Secretary-Treasurer, for the year of 1910, showing a balance of $179.84, and found them correct." (Signed) Robert J. Terry, Frederic T. Lewis.

On motion the report of the Treasurer and of the Auditing Committee were accepted and adopted.

The Committee on Nominations through its chairman, Milton J. Greenman, placed before the Association the names of Abram T. Kerr and Clarence M. Jackson, for members of the Executive Committee, for the term expiring 1914, in place of Thomas G. Lee and Irving Hardesty, whose terms of office expire.

On motion the Secretary was instructed to cast a ballot for the election of Abram T. Kerr and Clarence M. Jackson to membership of the Executive Committee for the term expiring 1914.

The following were recommended by the Executive Committee for election to membership in the Association:

Alexander Swanson Begg, Instructor in Embryology, *Drake University,*
Frank Ellsworth Blaisdell, Assistant Professor of Applied Anatomy, *Leland Stanford University, San Francisco.*
Floyd Earle Chidester, Senior Fellow in Biology, *Clark University.*
Alfred Einstein Cohn, Volunteer Assistant in Pathology, *Mt. Sinai Hospital, New York City.*
Calvin Brewster Coulter, *New York City.*
George W. Crile, Surgeon, *Western Reserve University, Cleveland.*

CHARLES H. DANFORTH, Instructor in Anatomy, *Washington University:* at present Austin Teaching Fellow in Histology, *Harvard.*
EVELYN JOHN EVATT. Professor of Anatomy, *Manitoba Medical College, Winnipeg, Canada.*
GEORGE FETTEROLF. Demonstrator of Anatomy, *University of Pennsylvania.*
CHARLES WILSON GREENE, Professor of Physiology, *University of Missouri.*
RICHARD WARREN HARVEY, Instructor in Anatomy, *University of California.*
MAXIMILIAN HERZOG, Professor of Pathology and Bacteriology, *Chicago Veterinary College, Pathologist to German and Alexian Brothers Hospital, Chicago.*
ARTHUR DOUGLASS HIRSCHFELDER, Associate in Medicine, *Johns Hopkins University.*
ALBERT KUNTZ, Fellow in Zoölogy, *State University of Iowa.*
LAUSON GENTRY LOWREY, Acting Professor of Anatomy, *University of Utah.*
ROLLO EUGENE MCCOTTER, Instructor of Anatomy, *University of Michigan.*
FRANK M. MACFARLAND, Professor of Histology, *Leland Stanford Jr. University, Stanford University, California.*
EDWARD FALL MALONE, Assistant Professor of Anatomy, *University of Cincinnati*
ALEXANDER MAXIMOW, Professor of Histology and Embryology, *Imperial Military Academy, St. Petersburg.*
CHARLES B. MORRILL, Assistant in Anatomy, *University and Bellevue Hospital Medical College.*
H. H. NEWMAN, Professor of Zoölogy, *University of Texas.*
ANDREW MELVILLE PATERSON, Professor of Anatomy, *University of Liverpool.*
JOHN THOMAS PATTERSON, Instructor in Physiology, University of Texas.
WILLIAM HUNTER PIERSOL. Associate Professor of Histology, and Embryology, *University of Toronto.*
HUGH DANIEL REED, Assistant Professor of Vertebrate Zoölogy, *Cornell University Ithaca, New York.*
PHILIP EDWARD SMITH, Assistant in Histology and Embryology. *Cornell University, Ithaca, New York.*
JOSEPH PRICE TUNIS, Instructor, *Philadeplhia Polyclinic.*
DAVID WATERSTON, Professor of Anatomy, *University of London, Kings College.*
ERNEST I. WERBER, Assistant in Anatomy, *Johns Hopkins University.*
HARRY LEWIS WIEMAN, Assistant Professor of Anatomy, *University of Cincinnati.*
LOUIS BLANCHARD WILSON, Pathologist and Director of Laboratories, *St. Mary's Hospital, Rochester, Minnesota.*

On motion the Secretary was instructed to cast a ballot for the election to membership in the American Association of Anatomists of applicants recommended by the Executive Committee.

The Executive Committee received the following resolution from the Board of Editors of the *American Journal of Anatomy:*

It is voted by the Board of Editors of the American Journal of Anatomy that beginning with the adoption of the bi-monthly in place of the tri-monthly rate of publication of this journal, only one volume of the *Journal of Anatomy* and one volume of the *Anatomical Record* shall be distributed annually as heretofore to the members of the American Association of Anatomists.

It was moved by the Executive Committee that the communication received from the editorial board of the *American Journal*

of Anatomy be presented to the Association at its business meeting.

This communication, transmitted to the Association through its Executive Committee, was accompanied by a statement from the Secretary, to the effect that in response to the circular and post cards sent to members of the Association, relative to increase in rate of publication of the *American Journal of Anatomy*, he had received 152 replies to questions one and two, (Question No. 1, Is it desirable to publish the *American Journal of Anatomy* at the rate of more than one volume a year? Question No. 2, Are you willing to subscribe to the extra volumes of the *American Journal of Anatomy* at the regular subscription price, namely, $5.00 a volume? [Payment of annual dues includes subscription to one volume of the *American Journal of Anatomy;* other volumes or parts of volumes published during the year are here designated as extra volumes.]) of which replies 110 members voted yes as to question one and two, while 42 voted in the negative on these questions.

After discussion it was moved that the Association approve of the plan adopted by the Board of Editors of the *American Journal of Anatomy*, namely, that this journal be published as a bi-monthly and that one volume of the *American Journal of Anatomy* and one volume of the *Anatomical Record* be distributed annually as heretofore to the members of the American Association of Anatomists.

At the last meeting of this Association, Dr. Bardeen of the University of Wisconsin presented a paper on "Practical State Board Examination in Anatomy." This paper was ordered printed in the *Anatomical Record* and on motion of the Society, the President was directed to appoint a committee to collect data and consider the question of State Board examinations and report to this Association at a future meeting. The President appointed as such a committee, Charles R. Bardeen, chairman, Franklin P. Mall, George A. Piersol. This committee had been collecting data during the past year and presented a set of resolutions to the Executive Committee for consideration. The Executive Committee after considering these resolutions, presented the following resolutions for consideration and adoption by this Association.

WHEREAS the examinations in Anatomy form an important and essential feature of the examinations given by State Boards of Medical Examiners to applicants for license to practice medicine and WHEREAS, it is desirable to test practically the knowledge of the candidate concerning the structure of the human body, therefore, be it resolved, that the American Association of Anatomists recommends to the Boards of Medical Examiners of the various states: First, that the acquaintance of the applicant with the chief organs and tissues of the body and with the fundamental topographical relations be tested by oral or written examinations on selected microscopical specimens, special gross anatomical preparations, and frozen sections; Second, be it resolved that the Executive Committee of the American Association of Anatomists stands ready to coöperate with the examining boards in the furtherance and execution of these plans.

On motion the Association approved and adopted the resolutions presented by the Executive Committee relative to Practical State Board Examinations in Anatomy.

It was further moved that the present Committee on Practical State Board Examinations in Anatomy be continued to carry into effect the resolution just adopted.

On motion the business meeting was adjourned.

Demonstrations from 3:30 to 5:30. (See announcement of demonstrations).

FRIDAY, DECEMBER 30, 9:00 A.M. TO 1:00 P.M. SESSION FOR THE READING OF PAPERS, PRESIDENT PIERSOL PRESIDING.

JAMES M. STOTSENBURG, *Wistar Institute of Anatomy.* On the effect of spaying in the albino rat.

HARVEY E. JORDAN, *University of Virginia.* The histology of the pineal gland.

BENJAMIN F. KINGSBURY. *Cornell University.* (a) The morphology of the mammalian ovary (Felis domestica). (b) The interstitial cells of the mammalian ovary. (c) Cytoplasmic fixation.

HAROLD D. SENIOR, *University and Bellevue Hospital Medical College.* The types of vascular system in the embryonic Teleosts.

ELIZABETH H. DUNN, *University of Chicago.* The presence of medullated nerve fibres passing from the spinal ganglion to the ventral nerve root in the frog. Rana pipiens. Read by title.

HANS LISSER, *Johns Hopkins University.* Studies on the development of the larynx. Read by title.

DAVENPORT HOOKER, *Yale University.* The development and function of the voluntary and caridac muscles in embryos without nerves.

BURTON D. MYERS, *Indiana University.* Certain features in the development of the cerebellum.

CHARLES R. STOCKARD, *Cornell University Medical School, New York City.* The fate of ovarian tissue when planted on different organs.

J. PARSONS SCHAEFFER, *Cornell University.* The ostium maxillare accessorium.

ABRAM T. KERR, *Cornell University.* A statistical study of the brachial plexus.

G. CARL HUBER, *University of Michigan.* A method of isolating complete mammalian uriniferous tubules.

At the end of this session, with which the twenty-seventh session of this Association was brought to a close, President Schurman and the local members of this Association were on motion tendered a vote of thanks for the efficient arrangements made and for their hearty coöperation in furthering the success of this meeting.

Demonstrations Presented

William H. F. Addison, *University of Pennsylvania.* Preparations showing the post-natal development of the cortical layer and cells of Purkinje in the albino rat.

Wesley M. Baldwin, *Cornell University Medical School, New York City.* (a) Specimens of double ureters; (b) skull presenting an unusual number of Wormian bones.

Montrose T. Burrows, *Rockefeller Institute.* Preparations illustrating the growth of tissues of the chick embryo outside of the body, especially preparations of the nervous system.

Eliot R. Clark, *Johns Hopkins University.* Drawings and specimens illustrating living, growing lymphatic and mesenchymal cells in the tail of the frog larva.

Melvin Dresbach, *Cornell University* (by invitation). Pancreatic bladder in the cat.

Simon H. Gage, *Cornell University.* (a) Demonstrations of the lampreys of the Cayuga lake basin; (b) demonstration of glycogen in lampreys before and after spawning.

Susanna P. Gage, *Ithaca, New York.* (a) Photographs and models of intercerebral sacs and fascia dentata in human embryos; (b) photographs and specimens showing the connection of the vomero-nasal nerve (terminal nerve) with the brain in the human embryo.

Davenport Hooker, *Yale University.* Models of heart of a normal frog embryo and of a nerveless frog embryo.

Grant S. Hopkins, *Cornell University.* Anatomical drawings.

G. Carl Huber, *University of Michigan.* Complete mammalian uriniferous tubules.

George S. Huntington, *Columbia University New York City.* Models and microscopic preparations illustrating the development of the lymphatic system in reptiles.

Clarence M. Jackson for Thos. J. Heldt and G. T. Kline, *University of Missouri.* Cross-section model of the head and neck.

Harvey E. Jordan, *University of Virginia.* Preparations of the pineal body of the sheep and the opossum.

Benjamin F. Kingsbury, *Cornell University.* Models of ovary (Felis domestica).

Adam M. Miller, *Columbia University, New York City.* Models and microscopic preparations showing the development of the jugular lymphsacs in birds.

H. D. Reed, *Cornell University* (by invitation). Models of developmental stages of skull of Erinaceus.

Edward L. Rice and Joseph I. Taggart, *Ohio Wesleyan University.* Models of embryonic skull and auditory labyrinth of Eumeces.

H. von W. Schulte, *Columbia University, New York.* Models and microscopic preparations illustrating the amniote homologies of the derivatives of the sulcus buccalis, and of the salivary glands of human embryos.

P. E. Smith, *Cornell University,* (by invitation). Models showing the development of the central nervous system of Desmognathus fusca.

Robert J. Terry and Victor E. Emmel, *Washington University, St. Louis.* A new dissecting microscope.

Robert J. Terry, for Charles H. Danforth, *Washington University.* A 74 mm. Polyodon.

Frederick Tilney, *Columbia University, New York City.* Models and microscopic preparation showing development of the axial venous and lymphatic systems in Tragulus memimna.

Leonard W. Williams, *Harvard University.* The *m.* subscapularis, *m.* serratus posticus superior, the flexor tendons, and the nerves of the panniculus carnosus in the Guinea pig.

G. Carl Huber,
Secretary-Treasurer.

THE DISTRIBUTION OF LYMPHOID TISSUE IN THE LUNG

WILLIAM SNOW MILLER

From the Anatomical Laboratory of the University of Wisconsin

THIRTEEN FIGURES

The distribution of lymphoid tissue within the lung, the situations in which it is to be sought and the relation which it bears to the air passages, the blood vessels, the lymph vessels and the pleura, has been passed over lightly in general descriptions of the histology of the lung.

The problem is of interest not only to the histologist but also to the pathologist; for these masses of lymphoid tissue frequently serve as centers to which, by means of the lymph vessels, disease processes may be conveyed.

The presence of lymphoid tissue and even of lymph nodes in the lung was recognized by many of the earlier investigators, notably by Burdon-Sanderson, Ruge, Klein, Schottelius and Frankenhäuser, but was generally regarded as pathological or of no special significance. The investigations of Arnold, however, established it as a constituent of the normal lung.

In an earlier contribution I have described the distribution of the lymph vessels in the lung and their relation to the air spaces, blood vessels and pleura, using the dog's lung as the basis of my study. In the present contribution I shall endeavor to show that there are definite places in which lymphoid tissue is to be sought and that it has a fairly constant relation to the various structures which go to make up the frame work of the lung.

THE ANATOMICAL RECORD, VOL. 5, NO. 3
MARCH, 1911

I shall, for convenience of description, consider lymphoid tissue:

1. *In its relation to the bronchi.*
2. *In its relation to the blood and lymph vessels.*
3. *In its relation to the pleura.*

LYMPHOID TISSUE IN ITS RELATION TO THE BRONCHI

According to Burdon-Sanderson, in the guinea pig,

> masses of cytogenic tissue of irregular form are always to be found in the neighborhood of the bronchi. Those which are in relation with the smaller branches lie in the loose connective tissue, by which these tubes, as well as the blood vessels are separated from the air cells; while those which lie near bronchi of sufficient size to be possessed of cartilages, are found to lie in a corresponding position outside of the fibrous layer in which the cartilages are embedded. In every instance I have found the adenoid masses occupying a position between the air tube and the nearest artery.

Frankenhäuser made a careful study of the trachea and bronchi in a number of animals and found in the bronchi of them all, including man, masses of lymphoid cells sometimes internal, sometimes external to the cartilages. Lymph nodes were found in the adventitia of the bronchi; usually at the place where branches were given off.

Arnold describes subpleural, perivascular and peribronchial masses of lymphoid tissue. In the walls of the bronchi of young children he failed to find in the normal lung, any masses of lymphoid tissue; they were always situated in the peribronchial connective tissue. In the walls of the bronchi of the adult, he also failed to find any distinct masses of lymphoid tissue.

Kölliker found in the walls of the bronchi of man masses of lymphoid tissue which closely resembled lymph follicles. Similar masses were also found in cartilagenous bronchi 2 to 3 mm and less in diameter and were in all cases situated between the cartilage and the tunica muscularis. In non-cartilagenous bronchi Kölliker failed to find any collection of lymphoid cells. On the other hand Stöhr and Kölliker, working on the lungs of the dog and rabbit, found small masses of lymphoid tissue in bronchi

0.1 to 0.3 mm. in diameter which in some cases extended into the mucosa. In the human lung Kölliker failed to find any lymphoid tissue in the mucosa. Both Verson and Dolkowsky have, however, described numerous small cells in the mucosa situated just beneath the epithelium and in some cases forming a distinct layer.

Toldt found in the larger bronchi numerous spherical cells scattered throughout the mucosa. In the medium sized bronchi he found, in normal lungs, scattered groups of lymphoid cells which were situated external to the tunica muscularis.

Oppel has found lymphoid tissue in the bronchi of representatives of the vertebrate phylum from monotremes to man.

Sukiennikow has described and figured the lymph nodes situated along the larger bronchi of the human lung. He found them quite constant at the place where branches were given off. His study did not extend as far as the non-cartilagenous bronchi.

In my own investigations I have used the lungs of man, the cat, dog, rabbit, guinea pig and rat. I have found along the larger bronchi not only scattered masses of lymphoid tissue but also lymph follicles and nodes. These latter were generally situated at the place where branches were given off. They did not, the rat excepted, extend beyond the tunica muscularis.

In bronchi which have cartilages in their walls the lymphoid tissue may be situated between the cartilage and the tunica muscularis, or outside of the cartilage in the peribronchial connective tissue, or in the space between two adjacent cartilages; the position seems to depend on the quantity of lymphoid tissue present.

In the rat the relations are somewhat different. In these animals there are no cartilages in the walls of the bronchi. The lymphoid tissue in their walls is often very abundant. Fig. 1 shows a section through a bronchus 1.45 mm. in diameter from the lung of the common brown rat (Mus decumanus), in which not only lymph follicles are present but also a diffused mass of lymphoid tissue which completely encircles the bronchus. In some places the lymphoid tissue penetrates the tunica muscularis and extends as far as the epithelium.

Two of the lymph follicles seen in fig. 1 are situated between the artery and bronchus, but they are not to be considered as belonging to the artery. The lymph vessels seen in section near the center of each do not belong to the pulmonary artery but to the system of lymph vessels situated in the wall of the bronchus.

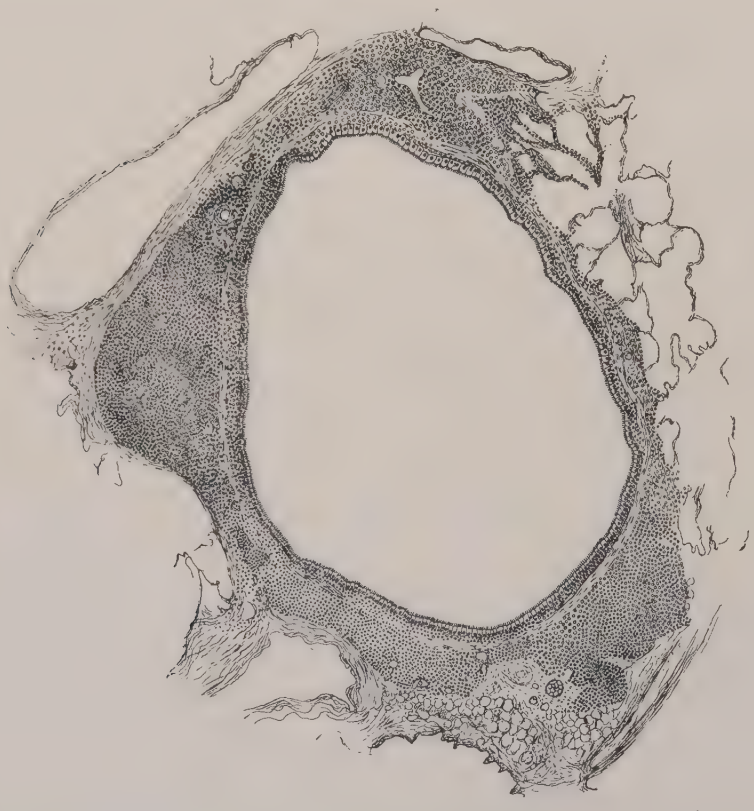

Fig. 1 Transverse section of a bronchus from the lung of the common brown rat. The lymphoid tissue surrounds the bronchus; in some places it is collected into follicles; in other places it may be seen breaking through the tunica muscularis and lying just beneath the epithelium. × 25.

Klein found, "in small bronchi which are devoid of cartilage, lymph follicles . . . . ., extending not only close up to the muscular coat, but also protruding through this latter into the proper mucosa, *i.e.*, into the layer between the epithelium and the muscularis."

My own results do not support this statement of Klein. I have failed to find in *normal* lungs along the bronchioli respiratorii and ductuli alveolares (non-cartilagenous bronchi) of man and of all the animals investigated distinct lymph follicles, but have found in each instance small masses of lympohid tissue which were

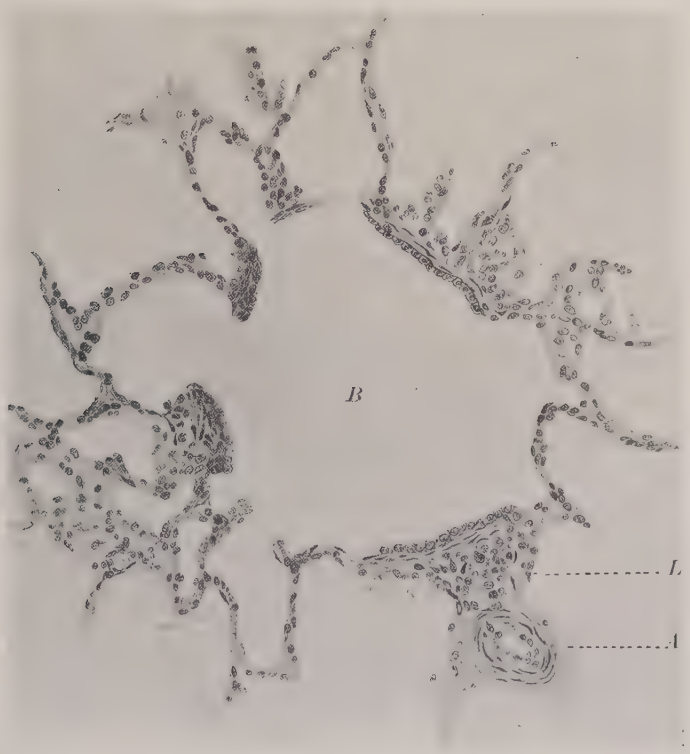

Fig. 2 Transverse section of a bronchiolus respiratorius from the lung of the cat. *B.*, Bronchiolus respiratorius; *A.*, Artery; L., Lymphoid tissue situated between the artery and bronchiolus. × 200.

situated outside the tunica muscularis between it and the accompanying branch of the pulmonary artery. Fig. 2 shows a section through a bronchiolus respiratorius of the cat, and exhibits the characteristic appearance of lymphoid tissue in this situation under normal conditions.

LYMPHOID TISSUE IN ITS RELATION TO THE BLOOD AND LYMPH VESSELS

For a complete understanding of the relation of lymphoid tissue to the pulmonary artery and vein it will be necessary to outline the distribution of both the blood and lymph vessels; because lymphoid tissue is intimately associated with the lymph vessels, and the lymph vessels accompany the blood vessels.

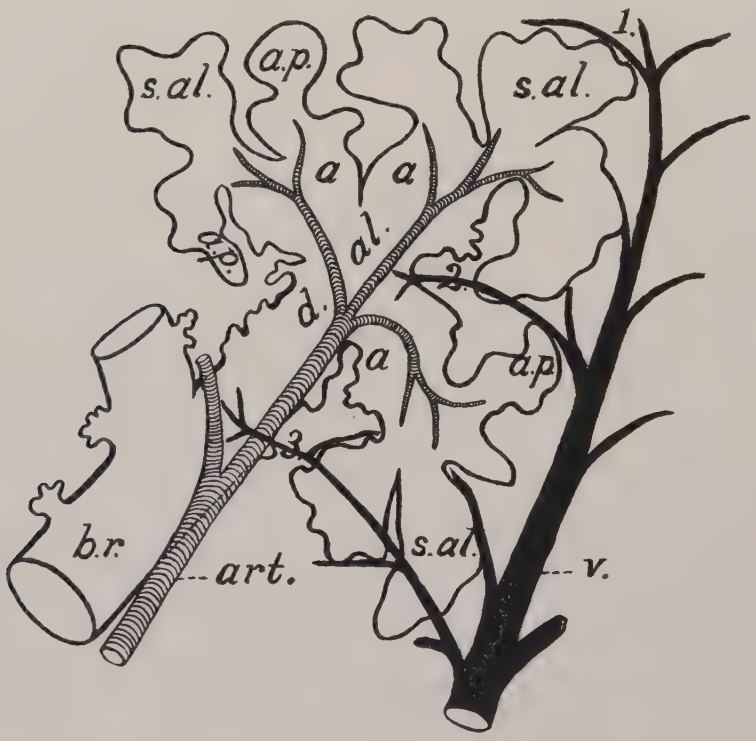

Fig. 3 Schematic longitudinal section of a primary lobule of the lung (the anatomical unit) showing the relation of the blood vessels to the air spaces. *b.r.*, Bronchiolus respiratorius; *d.al.*, Ductulus alveolaris; *a.a.a.*, Atria; *s.al.*, *s.al.*, Sacculi alveolares; *a.p.*, *a.p.*, Alveoli pulmonis; *art.*, Arteria pulmonalis with its branches to the atria and the sacculi; *v.*, Vena pulmonalis with branches from the pleura (*1*), from the ductulus alveolaris (*2*) and from the forking of the bronchiolus respiratorius (*3*). After Miller 1900.

The pulmonary artery follows the bronchus in all of its subdivisions, dividing as its divides, and ultimately comes to occupy a central position in the anatomical unit of the lung (fig. 3). Each has its system of lymph vessels which are in communication at the place where the bronchus divides and at the distal end of the ductulus alveolaris.

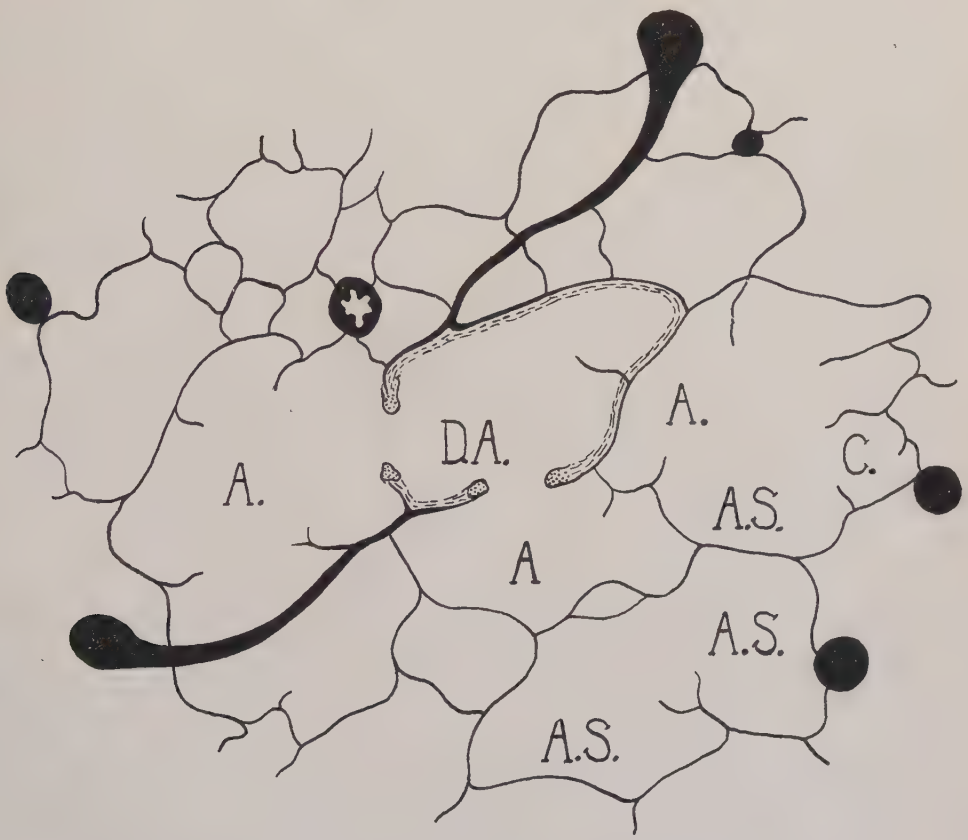

Fig. 4 Combination of three sctions taken through the center of a primary lobule of the lung of a dog. *D.A.*, Ductulus alveolaris; *A.A.A.*, Atria; *A.S A.S.*, *A.S.*, Sacculi alveolares; *C.*, Alveolus pulmonis. The tunica muscularis of the ductulus alveolaris is indicated by the broken lines. The pulmonary artery is indicated by the vessel with a stellate opening; the pulonary veins are in solid black. Note the two veins which arise from the ductulus alveolaris; they correspond to (*2*), in fig. 3. Camera lucida drawing. ×100. After Miller 1892.

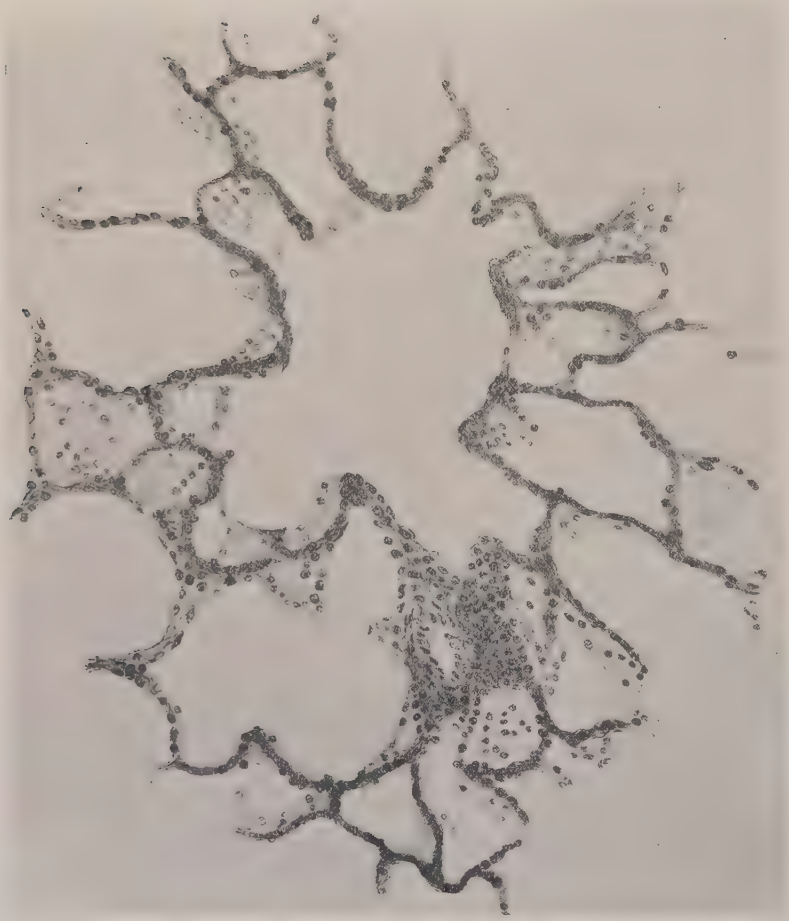

Fig. 5 Transverse section through a ductulus alveolaris from the lung of a cat. The small mass of lymphoid tissue is seen lying between the artery and the air spaces. The larger air space just above the artery is a portion of an atrium. × 200

The branches of the pulmonary vein, on the other hand, are situated on the periphery of the anatomical unit. In fig. 3 only one vein is shown, but there are always several of these veins arranged about the anatomical unit as is shown in a transverse section of the unit (fig. 4).

There is an important exception to the peripheral situation of the pulmonary vein; this is indicated in figs. 3 and 4. These venous radicles take their origin from the distal end of the ductulus alveolaris and consequently come to lie within the anatomical unit. There are two of these veins, one on either side (fig. 4), and they carry off the last remnant of the blood which is brought to the bronchus by the bronchial artery. All along the course of the bronchi, wherever a branch is given off, venous radicles take their origin. These radicles join one of the pulmonary veins (fig. 3, *3*). Like those within the anatomical unit they serve to carry blood from the bronchial to the pulmonary circulation.

The pulmonary veins, like the pulmonary artery, have a system of lymph vessels. They are in communication with the bronchial system at the place where the bronchus divides and at the distal end of the ductulus alveolaris where the bronchial system of lymph vessels terminates (fig. 3, *2* and *3*).

When lymphoid tissue is present along the course of the pulmonary artery it is situated between the artery and the adjoining air spaces rather than between the artery and bronchus, as is the case with bronchial lymphoid tissue. The lymphoid tissue may extend for some distance along the artery, but the sheath like arrangement described by some authors is not to be considered a normal arrangment. Fig. 5 is from a section taken through a ductulus alveolaris of a cat and shows lymphoid tissue lying between the artery and the adjoining air spaces, which in this instance are portions of atria. Only exceptionally have I seen lymph follicles along the course of the arterial lymph vessels. In the normal human lung I have failed to find them.

The presence of lymphoid tissue along the course of the pulmonary artery has been noted by nearly all who have studied its distribution in the lung; but the presence of lymphoid tissue along the course of the pulmonary veins has not been generally recognized.

If one of the small veins, which takes its origin from the distal end of a ductulus alveolaris (fig. 3, *2* and fig. 4) be followed until it joins one of the small trunks of the pulmonary vein situated at

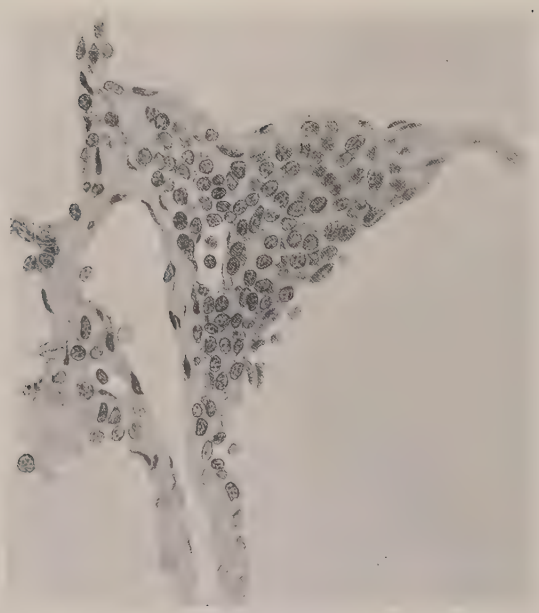

Fig. 6 Section from the lung of a cat showing the junction of one of the small veins taking its origin from the distal end of a ductulus alveolaris (fig. 4) with one of the main branches of the pulmonary vein situated on the periphery of a primary lobule. Two lymph vessels are shown in section; one on either side of the main branch. × 400.

the periphery of the anatomical unit, there will usually be found at the place of junction a small mass of lymphoid tissue as is shown in fig. 6. These masses of lymphoid tissue are situated in the adventitia and are associated with the lymph vessels which accompany the veins.

Not only do veins arise from the most distal end of a bronchus, but they also arise from the place where branches are given off (fig. 3, *3*). If we follow one of these branches it will be found that, where it joins one of the main trunks of the pulmonary vein, lymphoid tissue is present in greater or less quantity.

In fig. 7, which is taken from the lung of the rabbit, one of these veins is shown entering a large venous trunk. The amount of lymphoid tissue is small and in normal lungs may slightly exceed the quantity present in this section. As soon as any path-

Fig. 7 Section from the lung of a rabbit showing the junction of a vein, coming from a bronchus where it divides (see fig. 3, *3*), with a main branch of the pulmonary vein. In this section there are two small masses of lymphoid tissue; one, in the angle formed by the smaller vein with one of the main branches of the pulmonary vein and lying close to a lymph vessel; the other, situated on the opposite side of the vein, belongs to a second and larger vein which joins the main branch obliquely. × 165.

ological process occurs these small masses frequently become greatly augmented in size.

I have failed to find lymphoid tissue present where small venous radicles coming from the walls of the sacculi alveolares join other veins of similar size and origin.

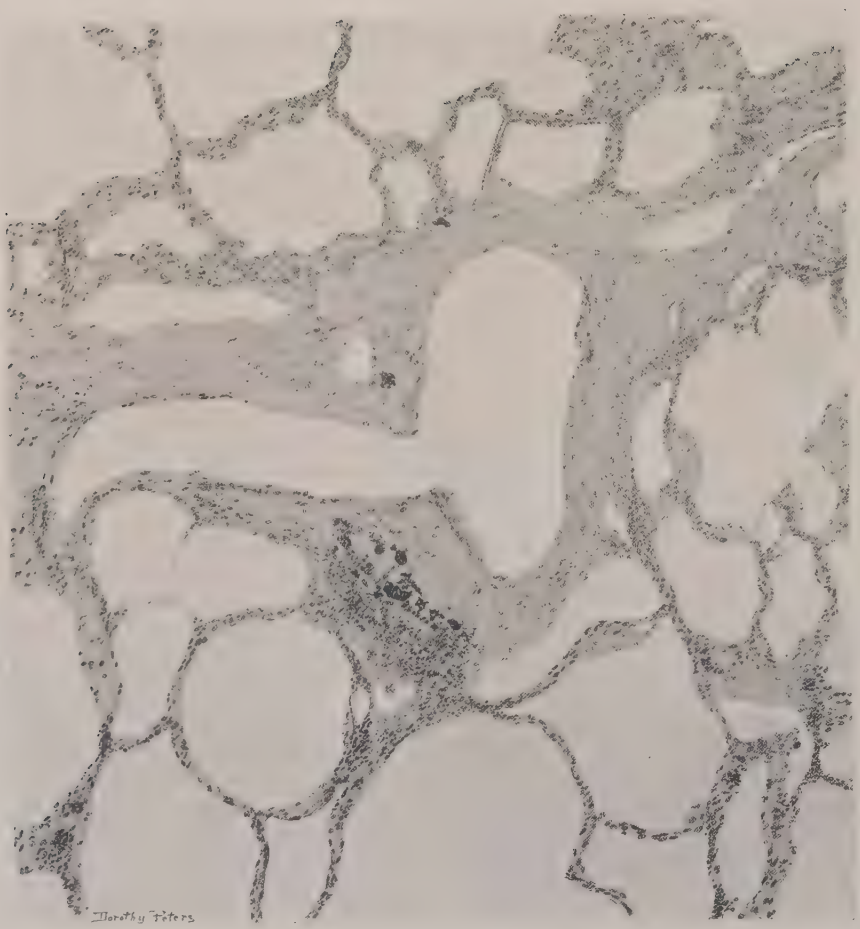

Fig. 8 Section of the human lung showing a branch, similar to that in fig. 7, joining one of the main branches of the pulmonary vein which, in this instance, is situated in a connective tissue septum between two secondary lobules. There is a moderate amount of pigment present. × 100.

In the human lung the same relation between lymphoid tissue and vein exists. Fig. 8 is taken from a section which shows the junction of a vein, coming from the place where one of the larger bronchi divides, with a venous trunk situated in one of the connective tissue septa of the lung. The presence of these masses of lymphoid tissue in the connective tissue septa has been noted by several observers, especially by Kölliker, but their relation to the vein was overlooked.

If only individual sections are studied not infrequently there will be found small masses of lymphoid tissue, apparently unassociated with blood or lymph vessels, situated in the parenchyma of the lung some distance from any bronchus. These isolated masses if they could be followed through a series of sections would, in nearly every instance, be found to belong to one of the masses of lymphoid tissue associated with the veins; in a few instances I have found such masses to belong to a bronchus situated immediately above or below the plane of the individual section being studied.

In like manner I have followed through serial sections numerous small miliary tubercles situated in the parenchyma of the lung; in every instance I have been able to trace their origin to one of the situations in which I have described lymphoid tissue as being present in the normal lung.

LYMPHOID TISSUE IN ITS RELATION TO THE PLEURA

The presence of lymphoid tissue in the normal pleura was established by Arnold and since then has been described by Lüders, Heller and other investigators. The amount of lymphoid tissue in the pleura is considerable, but I have failed to find in the *normal* pleura of man or of any animal which I have examined lymph follicles or nodes.

By referring to fig. 3 we see at 1, a pulmonary vein taking its origin from the pleura. As is shown in fig. 4 there are several of these veins about the periphery of each anatomical unit (the primary lobules). At the place where the pleural radicles unite

Fig. 9 Section of the pleura of a child four days old. No pigment is present. A small mass of lymphoid tissue is seen lying close to the lymph vessel, *L*. In the pleura can be seen a section of a radicle of the pulmonary vein *V*, and in the center of the section a small branch of the bronchial artery cut longitudinally. × 300.

to form a pulmonary vein we usually find a small mass of lymphoid tissue.

In the human lung there are connective tissue septa, much more highly developed than those about the primary lobules, which separate the secondary lobules from each other. In these septa blood and lymph vessels are associated with each other and where they join the pleural vessels there is always found a mass of lymphoid tissue.

The situation of the lymph follicles and nodes described by Lüders corresponds to the situation in which I find lymphoid tissue under normal conditions, but I can not recognize the lymph follicles and lymph nodes described by him and other investiga-

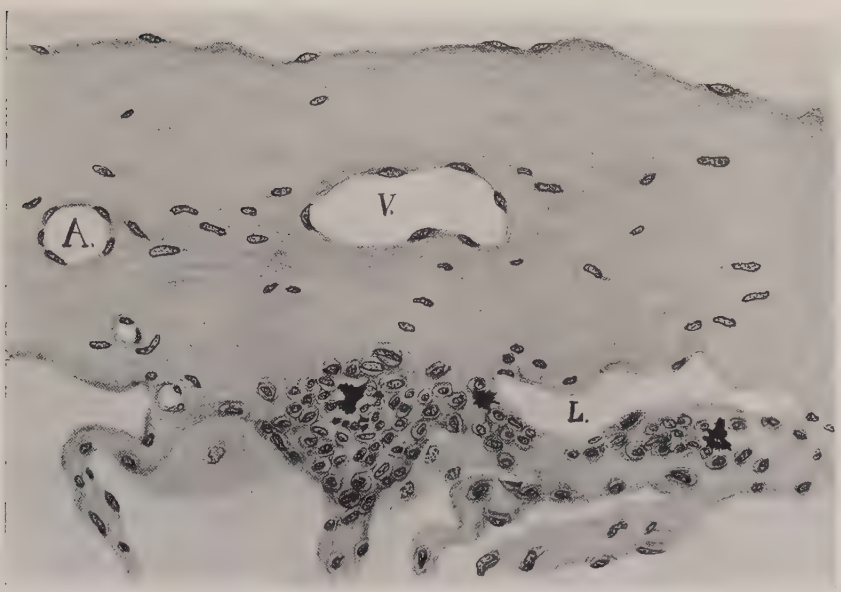

Fig. 10 Section of the pleura of a child seven years old. *A.*, Bronchial artery; *V.*, Pulmonary vein; *L.*, Lymph vessel. In the center of the section and just to the left of the lymph vessel, a mass of lymphoid tissue is seen; a second, and smaller, mass can be seen just beneath the lymph vessel. A small amount of pigment is present. × 300.

tors, in the pleura, as normal structures; they must be pathological and must have developed from the normal masses of lymphoid tissue. This development may arise from the presence of irritating substances as, for example, particles of carbon. In this case we find more or less pigmentation of the masses of lymphoid tissue and deposition of pigment along the course of the lymph vessels throughout the lung. In other cases we may have an hyperplasia of the already existing lymphoid tissue as, for example, in leucaemia. In these cases absence of pigment is the rule.

In fig. 9 we have a section taken through the pleura of a child four days old. No pigment is present and this may be taken as representing the amount of lymphoid tissue usually found in any one situation in the normal pleura of man before the deposition of any irritating substance.

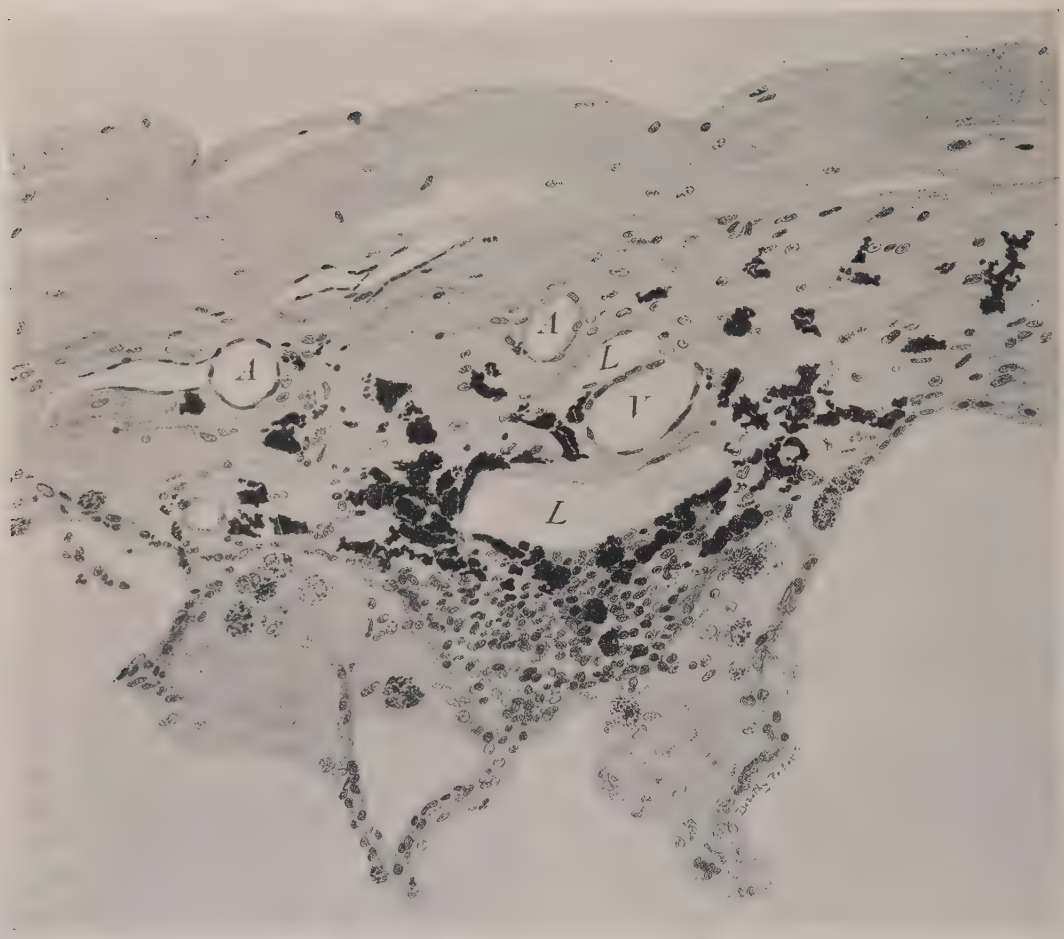

Fig. 11 Section taken perpendicular to the pleura of a man thirty-eight years old. A large amount of pigment is present. In the pleura we see sections of the bronchial artery, *A.A.*; of a radicle of the pulmonary vein *V.*; of lymph vessels, *L.L.* Just below the lymph vessels a mass of lymphoid tissue can be seen. Scattered about in the section are numerous phagocytes. × 250.

Fig. 10 shows a section taken through the pleura of a child seven years old; here we see that the amount of lymphoid tissue has materially increased, due no doubt to the presence of the small quantity of pigment.

Contrast these sections with fig. 11 which is taken through the pleura of a man thirty-eight years old. In this section we see a considerable quantity of pigment which is especially abundant about the lymph vessel. Scattered aggregations of pigment are present in the lymphoid tissue, which is more abundant than in fig. 10. Phagocytes laden with particles of carbon are to be seen in various parts of the section whose destination is the lymphoid tissue. Sections taken through other portions of the pleura show larger collections of pigment and consequently larger masses of lymphoid tissue. The increased amount of lymphoid tissue is undoubtedly due to the presence of the irritating particles of carbon.

What I have said in regard to the size of the lymphoid masses in the pleura, holds true of lymphoid tissue throughout the lung. I have already referred to this when describing the lymphoid tissue associated with veins.

The investigations of Shingu show that in children under twenty-three days old no pigmentation of the lung is present; from that time on pigment is always present but not always proportional to the age. It is undoubtedly true that the lungs of individuals living in an atmosphere charged with carbon contain a much greater quantity of pigment than those living in an atmosphere comparatively free from carbon, and my own investigations show a corresponding increase in lymphoid tissue. In fact I am forced to believe that in the lungs, contrary to what occurs in the alimentary tract, the quantity of lymphoid tissue increases from childhood to old age and that this increase is largely due to the irritation arising from the constant inhalation of irritating substances.

The mode by which particles of carbon are removed from the air spaces and deposited in these masses of lymphoid tissue and along the course of the lymph vessels is of interest. I have not been able to examine any considerable quantity of pathological material. I shall therefore confine my statements to normal material.

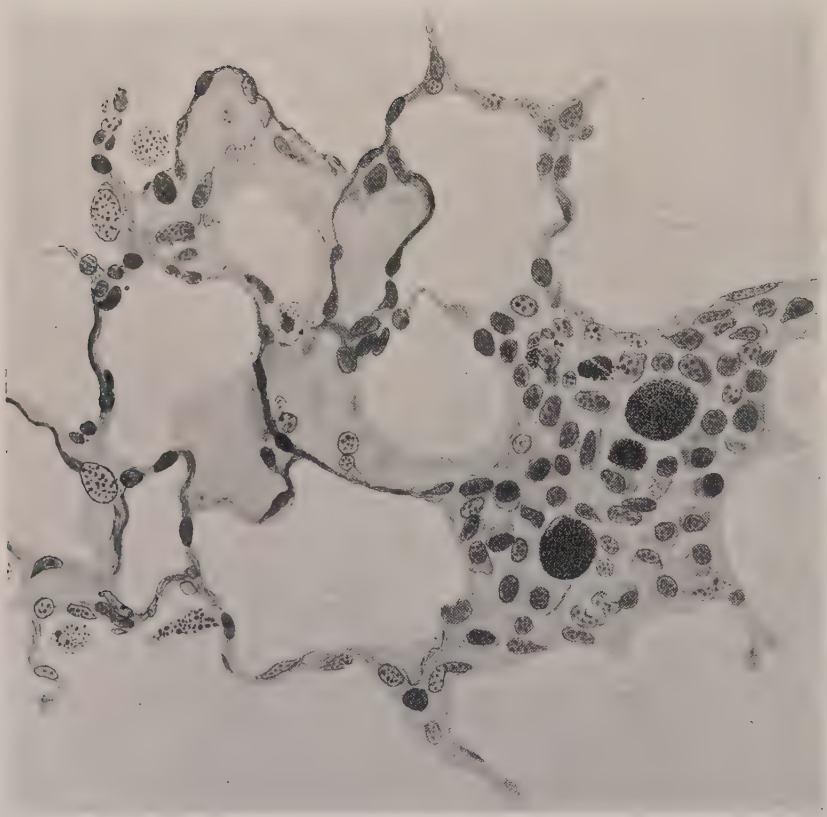

Fig. 12 Section of the lung of a rat. Phagocytes in various stages of activity can be seen. Some of them are free in the air spaces; others are in close apposition with the walls of the alveoli, while still others are within the mass of lymphoid tissue. Two large macrophages show prominently in the lymphoid tissue. × 500.

When particles of carbon are inhaled it is, as a rule, only the finer particles that penetrate as far as the alveoli pulmonis. Here the particles come in contact with the epithelium covering the walls of the alveoli and may frequently be seen lying free on their surface. I have been unable to convince myself that the normal pulmonary epithelium becomes phagocytic; on the other hand many phagocytes, more or less laden with particles of carbon, are present in each alveolus and the question arises, what is their origin?

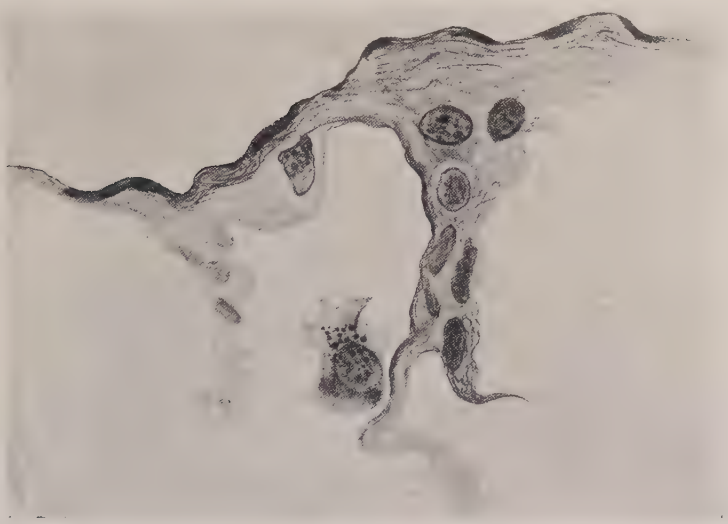

Fig. 13 An active phagocyte from the lung of a rat. × 600.

Briefly answered, they are mononuclear lymphocytes derived from the masses of lymphoid tissue or from the blood vascular circulation. In fig. 6 cells in various stages of activity, free from pigment can be seen lying just outside of the small mass of lymphoid tissue and along the wall of the blood vessel.

The most interesting sections I have studied were taken from the lung of a common brown rat which was caught in the coal bunkers of a large steam heating plant. Figure 12 shows a portion of a section of the lung in which phagocytes in various stages of activity are seen more or less laden with pigment. Some of these are free within the alveoli, others are within the walls of the alveoli while still others have found their way into the mass of lymphoid tissue where they have deposited their contents.

Fig. 13 shows the most striking example of a phagocyte I have met with. That this, and similar cells, are not derived from the epithelium, is demonstrated by a careful study of the nucleus which does not coincide in structure with that of the epithelium but does coincide with that of the mononuclear lymphocyte.

SUMMARY

Lymphoid tissue, as found in the lung, may be peribronchial, periarterial, perivenous or subpleural.

Lymphoid tissue in the lung may be in the form of lymph nodes, lymph follicles or small masses of lymphoid tissue.

Lymph nodes, in the normal lung, are found associated with the larger divisions of the bronchi. They are situated at the place where branching takes place. In the normal lung lymph nodes are not present in the pleura.

The smaller masses of lymphoid tissue may, like the lymph nodes, act as filters interpolated in the lymph circulation. They also serve as centers to which the phagocytes carry their collected material.

On account of the arrangement of the blood vessels, the masses of lymphoid tissue are found in the greatest number at the periphery of the primary and secondary lobules.

The normal respiratory epithelium does not become phagocytic.

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DUODENAL DIVERTICULA IN MAN

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TWENTY-SIX FIGURES

Generally speaking diverticula of the duodenum are rare in comparison to the number of diverticula described in the literature as occurring elsewhere in the intestine. These have been divided by most authors into two classes, congenital and acquired, which are terms sufficiently explanatory in themselves. There are also two sub-groups known as 'true' and 'false,' the basis of this division being entirely anatomical. A 'true' acquired diverticulum presents in its walls all coats of the normal intestine, *i.e.*, mucosa, submucosa, muscularis, and peritoneum (fig. 1). The presence or absence of the last named constituent depends, however, upon the site of the diverticulum, namely, whether arising from the mesenteric border of the gut and thus projecting between the layers of the mesentery or whether situated along the convex free surface of the intestine. On the other hand, in the 'false' variety of acquired diverticula the muscularis is wanting, the walls, then, being formed by mucosa and submucosa alone. Accordingly, one might readily conceive of this form as being a hernia of the mucosa with the submucosa through a rent in the muscular layers of the intestine, and this conception has been verified in some instances by actual findings of diverticula in which the muscularis ceased abruptly at the orifice of the sac (fig. 2).

This Cornell series of duodenal diverticula is remarkable for two reasons: first, that so large a number as fifteen should be discovered among a series of only 105 duodena, and, secondly, because of the fact that the series includes the largest diverticulum yet mentioned.

For purposes of convenience in the matter of description of these specimens, I have divided them into the following classes based upon their gross anatomical form. In fig. 3, *a*, represents a funnel-shaped diverticulum, *b*, a tubular or cylindrical form, and *c*, a spherical or globular diverticulum.

Further, with the idea of making this paper a complete presentation of the subject of duodenal diverticula, I have collected the descriptions of the specimens heretofore reported in the literature and herewith present them in abstracted form.

The Cornell series

Specimen 1. (Figs. 4 and 5) This specimen (no. 353) was removed from the body of a white male, age 65, weight 150 (estimated), who had died of senility. Six centimeters caudal to the major duodenal papilla a wide-mouthed, funnel-shaped diverticulum opened upon the cephalic surface of the third portion of the duodenum. The sac extended cephalad a distance of 1.0 cm. lying dorsal to the head of the pancreas but did not penetrate it. The fundus measured 2.0 cm. transversely by 0.7 cm. in the dorso-ventral direction. The structure of the sac-wall was similar to that of the duodenum, all of the coats, however, being reduced in thickness. There was no relation of the fundus to any of the large vessels or to the ducts of the pancreas.

Specimen 2. (Figs. 6 and 7) The history of this specimen was not available (s795). In the descending portion of the duodenum there was a large diverticulum with a circular orifice 1.5 cm. in diameter. The fundus, globular in shape, extended medially a distance of 2.5 cm., lay dorsal to the head of the pancreas and possessed an approximate diameter of 2.0 cm. The bile and main pancreatic ducts traversed the ventral wall of the sac, opening at the ventro-caudal angle of its orifice. The minor papilla was not related to the diverticulum. The mucosal lining presented several folds, but the structure of the wall differed in no particular from that of the duodenum excepting that all the layers were thinner and the glands less numerous.

Specimen 3. (Fig. 8) White female, age 82, 5 feet, 2 inches tall, weight 140 (estimated), died of dysentery (no. 287). In this

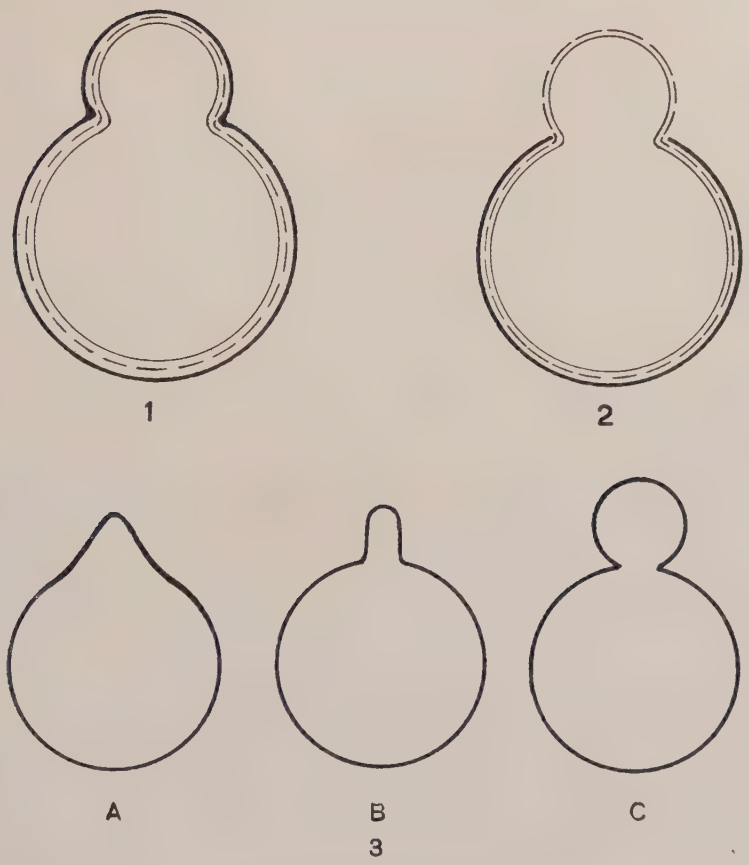

Fig. 1 In this diagram the intestine is represented in cross-section with a 'true' acquired diverticulum opening into it. The thin inner line represents mucosa, the interrupted line, submucosa, while the heavy line represents the intestinal muscularis. As is to be seen, all three layers are carried uninterruptedly over the fundus of the sac.

Fig. 2 In this diagram a 'false' acquired diverticulum is figured opening into the intestine. The muscularis, represented by the heavy outer line, ends abruptly at the mouth of the diverticulum, the mucosa and submucosa, however, represented by the thin inner line and the broken line, respectively, constitute the wall of the diverticulum.

subject a diverticulum of unusual size projected into the head of the pancreas from the medial wall of the descending portion of the duodenum. Its communication with the duodenum measured 4.0 cm. in the long axis of the intestine by 2.5 cm. transversely, being somewhat quadrilateral in shape. The fundus, loosely attached to the substance of the pancreas which encompassed it, presented proportions approximately equal to those of the head of the gland, *i.e.*, it measured 6.0 cm. cephalo-caudally, 3.0 cm. dorso-ventrally, and 4.0 cm. transversely. Within the sac a prominent fold of mucosa 0.9 cm. broad and 2.2 cm. long passed cephalo-caudally across the dorsal wall. The bile duct, traversing this fold at some distance from its free edge, terminated at the major duodenal papilla 1.0 cm. within the sac at the junction of its dorsal and caudal walls. The main pancreatic duct passed dorsal to the diverticulum to open at the major papilla with the bile duct. Upon the duodenal mucosa, cephalad and ventral to the orifice and about 1.0 cm. from it, lay the minor duodenal papilla with the opening of the accessory pancreatic duct, the latter traversing the pancreatic substance of the head of the gland ventral to the fundus of the diverticulum. The mucosa of the diverticulum was smooth with but few villi, and devoid of intestinal valves and of intestinal glands. A single thin layer of muscularis existed over the fundus and became somewhat thickened at the orifice of the sac. Numerous large blood vessels were to be seen distributed along the parietes.

Specimen 4. (Figs. 9 and 10) This specimen (no. 433) was removed from the body of a white female, age 53, weight 98, diagnosis 'heart disease.' Lying directly cephalad and dorsal to the major duodenal papilla in the second or descending portion of the duodenum an orifice, measuring 0.7 cm. transversely and 0.5 cm. in the long axis of the intestine, communicated with a spherical diverticulum. The fundus of this sac, with dimensions somewhat more ample than those of the orifice, lay dorsal to the head of the pancreas, to which it was adherent by loose connective tissue fibrils, and extended medially a distance of 0.5 cm. The sac bore no immediate relation to the orifice of the accessory pancreatic duct, but both the main pancreatic and bile ducts traversed its

ventro-caudal wall. No sphincter-like arrangement of the duodenal muscularis existed at the orifice of the sac. All of the elements of the duodenal wall were represented in the parietes of the diverticulum.

Specimen 5. (Fig. 11) Male, age 55, white, weight 140 pounds (estimated), height 5 feet 7 inches, diagnosis cerebral hemorrhage (no. 377). The medial wall of the descending portion of the duodenum presented a quadrilateral orifice with sharp and well-defined edges measuring 2.5 cm. in the long axis of the intestine and 1.5 cm. transversely. This orifice opened into a large spherical diverticulum which projected medially a distance of 2.5 cm. into the substance of the head of the pancreas midway between its dorsal and ventral surfaces. The fundus measured 3.0 cm. cephalo-caudally by 1.0 cm. dorso-ventrally. The bile duct in company with the main pancreatic duct traversed the dorsal wall of the sac, both opening at the major papilla which was situated 0.7 cm. within the orifice upon the dorsal wall of the diverticulum. A prominent fold of mucosa bearing this papilla upon its crest ran caudally across the dorsal wall. The minor papilla was located upon the duodenal mucosa 1.2 cm. cephalad and ventral to the diverticulum. Microscopically the fundus showed a thin muscularis completely investing the sac. No sphincter was present. The villi were more scattered over the fundus.

Specimen 6. (Figs. 12 and 13) The data in this case (s503x) were not obtainable. At the common orifice of the bile and main pancreatic ducts a globular diverticulum 1.5 cm. in depth and 1.2 cm. in the other dimensions, lying dorsal to the head of the pancreas, opened into the duodenum through an irregularly quadrilateral orifice measuring 1.1 cm. in the long axis of the duodenum and 0.4 cm. transversely. The ducts lay along the caudal wall of the sac with their orifice at its caudal lip. With the exception of the one-layered structure of the muscularis and the thinness of the several coats in general, the constituents of the wall of the sac did not differ from those of the duodenum. There was no sphincter at the orifice.

Specimen 7. (Fig. 14) Female, age 61, white, height 5 feet 6 inches, weight 150 (estimated), death from sepsis (no. 341). The

figure represents a small, shallow, funnel-shaped diverticulum upon the medial wall of the second portion of the duodenum presenting in its depth the conjoined orifice of the bile and main pancreatic ducts. The structure of the parietes of the depression was precisely similar to that of the duodenal wall. This diverticulum presented an orifice 0.4 cm. in diameter and a depth of but 0.2 cm.

Specimen 8. (Figs. 15 and 16) Male, age 60, white, height 5 feet 8 inches, weight 160 (estimated), diagnosis endocarditis (no. 330). In this specimen a large diverticulum communicated through a comparatively small orifice with the duodenum 4.5 cm. caudal to the major duodenal papilla. The body of the diverticulum lay dorsal to the caudal portion of the head of the pancreas and measured 3.0 cm. in a cephalo-caudal direction, 2.0 cm. transversely, and 0.7 cm. in the dorso-ventral axis. The orifice was irregularly oval, the long axis, parallel to that of the duodenum, being 1.0 cm. while the transverse axis measured 0.5 cm. There existed at the orifice a sphincter-like ring of muscularis. The walls of the sac were somewhat attenuated especially over the fundus. The mucosa presented numerous folds representing intestinal valves but did not differ in other respects from that of the duodenum.

Specimen 9. (Figs. 17 and 18) Male, age 47, white, height 5 feet 6 inches, weight 140 (estimated), diagnosis 'consumption' (no. 363). At the summit of the duodeno-jejunal flexure a wide-mouthed, funnel-shaped diverticulum extended cephalad a distance of 1.0 cm. and lay dorsal to the head of the pancreas. Neither of the pancreatic ducts bore any relation to the diverticulum. The muscularis did not present a sphincter-like arrangement at the orifice, nor did the structure of the walls differ in any respect from that of the duodenal wall. No large vessels were in association with the fundus of the sac.

Specimen 10. (Figs. 19 and 20) Male, age unknown, white, height 5 feet 8 inches, weight 140 (estimated), diagnosis chronic bronchitis (no. 305). This cylindrical diverticulum lay directly cephalad to the major duodenal papilla, the common bile duct passing along its ventro-caudal wall. The orifice, irregularly

round, measured approximately 0.4 cm. There was no sphincter. The diverticulum passed medially and cephalically a distance of 1.0 cm. adjacent to the common bile duct and lying wholly behind the head of the pancreas. The minor duodenal papilla and the accessory pancreatic duct had no immediate relation to the diverticulum. The walls presented the usual elements of the intestinal wall, however, somewhat thinned.

Specimen 11. (Fig. 21) Male, age 59, white, height 5 feet, weight 160 (estimated), death from 'heart disease' (no. 308). This shallow diverticulum extended only 0.4 cm. from the cephalic wall of the transverse portion of the duodenum towards but not into the head of the pancreas. It lay 6.5 cm. caudal to the orifice of the bile duct and its orifice measured 0.5 cm. in diameter.

Specimens 12 and 13. (Fig. 22) The data in this specimen (s503) could not be obtained. There were two small, cylindrical diverticula situated side by side on the same transverse plane immediately cephalad to the minor papilla but with no immediate relation to the accessory pancreatic duct. Each measured 0.3 cm. in width by 0.4 cm. in depth. The fundus of each was buried in the tissue of the head of the pancreas. Their walls presented a normal mucosa and submucosa; the circular muscularis was thickened at the orifice to form a sphincter, the muscularis then became thinner and formed a single stratum over the fundus.

Specimen 14. (Figs. 23 and 24) The data in the history of this specimen (s804) could not be ascertained. Located upon the cephalic surface of the transverse portion of the duodenum 6.0 cm. caudal to the major duodenal papilla a small tubular diverticulum 1.0 cm. deep lay dorsal to the head of the pancreas. This diverticulum measured 0.5 cm. in transverse diameter and 0.3 cm. dorso-ventrally. The orifice measured only 0.2 cm. in the long axis of the duodenum and but 0.1 cm. transversely. The muscular stratum covering the fundus of the diverticulum was very thin; in other respects, however, the wall did not differ from that of the duodenum. Most of the muscle fibres covering the fundus were derived from the circular layer of the intestine. The ducts of the pancreas, of course, had no relation to the fundus of the sac.

Specimen 15. (Figs. 25 and 26) Male, age 56, white, height 5 feet 7 in., weight 140 (estimated), death from dysentery (no. 365). Five centimeters caudal to the major duodenal papilla upon the cephalic surface of the third portion of the duodenum a large funnel-shaped diverticulum projected towards the dorsal surface of the head of the pancreas. The side walls sloped gently towards the fundus of the sac, whose maximum depth approximated 1.0 cm. At the orifice, where the dimensions were greatest, the long diameter measured 2.5 cm. in the direction of the long axis of the duodenum with the transverse dimension 2.0 cm. The walls of the sac possessed all the coats of the duodenum, the muscularis being represented, however, by only a thin stratum of muscle fibres. The ducts of the pancreas bore no relation to the sac.

The essential facts of the Cornell series may be briefly stated as follows. One duodenum presented two diverticula which were located immediately cephalad to the minor duodenal papilla. Six of the diverticula were in the pars inferior duodeni while the other seven lay in immediate relation to the major duodenal papilla. All of these diverticula were situated upon the left or concave side of the duodenum extending towards the pancreas. Four projected directly into the gland, eight lay behind, while the other three were caudal to the head of the gland. None of the diverticula presented any evidences of inflammatory conditions. All of them belonged to the 'true' variety.

Following are the descriptions collected from the literature

While these abstracts have been made as brief as possible an effort has been made to keep closely to the exact wording of the original in the matter of the size, shape, etc., of the diverticula.

The first duodenal diverticulum mentioned in the literature was described by Morgagni in 1761. This specimen, which was obtained from the body of a man who had died of apoplexy, was situated two finger-breadths caudal to the pylorus, the orifice being large enough to admit a finger. The sac exhibited no traces of pathological changes.

Rahn (1796) found a duodenal diverticulum in the emaciated body of a woman 22 years old who had died of chronic emesis. This sac-shaped diverticulum was closely related to the pylorus and presented a mucosal fold at its orifice not unlike that of the pylorus. The condition of gastroptosis was present in this cadaver.

Fleischmann ('15) reported the following specimens:

Specimen 1. Male, 64, had used brandy freely, killed. The common bile duct opened into a bladder-like diverticulum of the duodenum. Likewise the pancreatic duct opened into a similar adjacent but smaller diverticulum. The orifice of the larger diverticulum was devoid of intestinal valves. The walls of these sacs were thin and lacking of muscularis save at the orifice where a sphincter-like arrangement existed.

Specimen 2. Male, old age. The common bile duct opened into a bladder-shaped diverticulum of the duodenum. Adjacent there were three similar diverticula with lengths of a quarter, a half, and a full inch respectively. Two of these were bladder-shaped; the third, and largest, was constricted and pointed. The orifice of each presented a sphincter of muscularis and a crescentric fold of mucosa. The intestinal valves of the neighborhood were deficient.

Specimen 3. Male, 28, drowned. The ductus pancreaticus and the ductus choledochus opened separately each through a small duodenal diverticulum. Lying near these diverticula there was a third of the size of a pigeon's egg and, towards the first portion of the duodenum, still another smaller though similar diverticulum.

Albers ('44) mentioned one diverticulum located in the horizontal portion of the duodenum. It was scarcely one inch long and presented a contracted orifice with a marked fold of mucosa.

Barth ('51) reported in a female, aged 60, a duodenal diverticulum, composed of all of the coats of the intestine, penetrating the head of the pancreas and of a size sufficient to admit the little finger. This diverticulum seemed independent of the pancreatic ducts.

Habershon ('57) remarked having seen in Guy's museum a duodenal diverticulum near the orifice of the bile duct, but gave no further description of the specimen.

Roth ('72) reported the following series of specimens:

Specimen 1. Male, workman, 50, dead from a blow on the head. In the descending portion of the duodenum, 3 cm. cephalad to the orifice of the common bile duct and 0.5 cm. cephalad to the minor papilla, there was a finger-like pouch 1.5 cm. long running caudally and medially into the head of the pancreas. The fundus was covered ventrally by a thin layer of pancreatic tissue with a thicker layer dorsally. The muscularis existed only at the orifice in the form of a sphincter; elsewhere the walls were constituted by mucosa and a thin layer of connective tissue.

Specimen 2. Male, 69, emaciated. At the level of the orifice of the ductus choledochus, *i.e.*, in this specimen, the junction of the pars descendens and pars transversus inferior duodeni, a cylindrical diverticulum communicated with the duodenum through an orifice as large as a pea and extended 1.5 cm. along the bile duct into the head of the pancreas. Its walls were composed of thin mucosa and a thin layer of connective tissue. A second diverticulum, similar in form, direction and extent of long axis, structure, and in relations, existed 1.5 cm. cephalad to it. These diverticula were separated from each other by a thin layer of pancreatic tissue and by the common bile and pancreatic ducts. A promi-

nent fold of mucosa limited the constricted orifices. The muscle fibres of the duodenum evidenced fatty degeneration.

Specimen 3. Male, 67, emaciated. Three centimeters cephalad to the orifice of the common bile duct a diverticulum of the duodenum of the size of a walnut penetrated the head of the pancreas. This rounded diverticulum was composed of mucosa. Its orifice was of the size of a lentil.

Specimen 4. Male, 58, emaciated. In the descending portion of the duodenum there was a diverticulum of the size of a hazelnut.

Specimen 5. Female, 49, emaciated. In the descending portion of the duodenum two thin-walled diverticula, one smaller and medial to the orifice of the ductus choledochus, the other, more cephalad and as large as a cherry, projected towards the head of the pancreas. The larger communicated with the duodenum through an orifice sufficient to admit the little finger.

Schüppel ('76) reported that he found a duodenal diverticulum present in seven instances among 45 bodies studied. At Kiel, however, among 200 bodies he found but one diverticulum.

Schirmer ('93) mentioned two specimens. The first, 2.2 cm. cephalad to the orifice of the common bile duct, was 2.5 cm. deep and 1.3 cm. broad; through the second, of the size of a pea, the accessory pancreatic duct communicated with the duodenum.

Under the heading "Large Pseudo-Diverticulum of the Duodenum," Pilcher ('94) described a pathological curiosity into which the duodenum opened and from which the jejunum passed. The sac presented mucosa in only one small strip. Elsewhere the parietes were devoid of epithelial lining and exhibited inflammatory changes.

Good ('94) collected five specimens. Two of these received mere mention, one being from the body of a female of twenty-seven who had died of cholera nostras.

Specimen 1. Female, 77. Lateral and cephalad to the orifice of the common bile duct a duodenal diverticulum of the size of a plum extended into the head of the pancreas. The muscularis, deficient over the fundus of the sac, existed at the constricted orifice in the form of a sphincter.

Specimen 2. Female, 54, died of carcinoma of the ovary with metastatic involvement of the liver and peritoneum. One and a half centimeters cephalad and to the right of the orifice of the bile duct a thin-walled cylindrical diverticulum 2.2 cm. deep communicated with the duodenum through an orifice 0.9 cm. in diameter. The bile duct passed ventral and to the right of the sac while a layer of pancreatic tissue 0.5 cm. thick lay dorsal to it. The parietes contained no muscle fibres.

Specimen 3. Female, 51. A spherical diverticulum 1.8 cm. in diameter opened into the duodenum 3.5 cm. cephalad and 1.4 cm. medial to the orifice of the bile duct and 10.0 cm. caudal to the pylorus. The fundus projected medially a distance of 2.5 cm. into the substance of the head of the pancreas, which separated it from the bile duct. No muscle

fibres were present in the wall of the sac nor did the mucosa present any folds.

Seippel ('95) reported a cylindrical diverticulum of the duodenum at the level of the major duodenal papilla, 5.0 cm. in diameter and extending about 3.0 cm. dorsally and cephalically, the fundus being surrounded by pancreatic tissue. Microscopically the wall of the sac revealed a mucosa, somewhat thinned, a muscularis, and a muscularis mucosae. No other muscle fibres were prolonged over the fundus of the sac, the muscularis being represented there by a thin layer of connective tissue.

Hansemann ('96) reported a specimen of multiple diverticula in a man of 85 who had died of pneumonia. He had been fat. The intestine contained about 400 diverticula varying in size from a hemp-seed to a pigeon's egg. Several isolated examples were in the duodenum, but no description of these diverticula was given.

Helly ('98) saw in a duodenum two diverticula, one located above each papilla. The caudal of the two, corresponding to the major papilla extended into the head of the pancreas.

Charpy (98) reported one specimen taken from the body of an aged woman. The main pancreatic duct was small and terminated blindly at a cul-de-sac of the duodenal wall. In another specimen a small diverticulum caudal to the orifice of the bile duct opened into the ampulla of Vater but was not associated with either duct.

Letulle ('99) described two specimens. The first, of a depth of from 1.5 cm. to 1.6 cm., was composed of mucosa, with a few intestinal glands and no duodenal glands, of muscularis mucosae and of connective tissue. The muscularis of the duodenum ended abruptly at the orifice of the diverticulum. In the other specimen five pouches were grouped about the common orifice of the main pancreatic and common bile ducts, four being cephalad and one caudal. These pouches extended medially towards the head of the pancreas, but did not penetrate it.

Nattan-Larrier ('99) described a duodenum in which the common bile duct emptied into a small cul-de-sac containing also the orifice of the main pancreatic duct.

Marie ('99) says that he found in the body of a man of 45 a duodenum which presented two diverticula. The larger extended about 5.0 cm. medially, dorsal to the head of the pancreas and communicated with the duodenum by a constricted orifice 2.0 cm. in diameter. Both the bile and the pancreatic ducts opened at the mouth of the sac. The other smaller but similar diverticulum, 1.5 cm. deep, lay more cephalad and opened into the duodenum through a rounded orifice 1.0 cm. in diameter. The mucous lining of these diverticula was thin, smooth, devoid of villi, and of duodenal glands, there remaining but little else than a layer of cylindrical epithelium. The muscularis of the duodenum stopped abruptly at the orifice of the sac which it surrounded in the form of a ring.

Jach ('99) made the following report:

Specimen 1. Female, 64. On either side of the major duodenal papilla a diverticulum extended into the substance of the head of the pan-

creas with the bile duct lying between them. The larger or medial of these two was as large as an egg, globular in shape and possessed a somewhat constricted orifice sufficiently ample, however, to admit two fingers. The pancreatic duct traversed its caudal wall. The smaller, lateral diverticulum was as large as a walnut. Four centimeters caudal to the major papilla two diverticula of the size of a cherry and with orifices admitting the little finger, lay about 2.0 cm. apart, one being caudal and medial to the other. Their dorsal surfaces were not covered with pancreatic substance.

Specimen 2. Immediately caudal to the pylorus a cylindrical diverticulum with a mouth large enough to admit the thumb extended 3.0 cm. caudally, dorsally, and medially from the first portion of the duodenum. Because of its cephalad position this diverticulum had no relation either to the major duodenal papilla or to the head of the pancreas.

Specimen 3. Male, 58, carcinoma of the rectum. In the first portion of the duodenum 2.0 cm. from the pylorus there was an obliquely placed cicatrix. Between this and the pylorus an orifice large enough to admit one finger opened into a spherical diverticulum 1.0 cm. deep, the fundus of which passed cephalad to the pylorus. Its dorsal surface was not covered with pancreatic tissue.

Rolleston and Fenton ('00) described three specimens:

Specimen 1. Female, emaciated, hepatic cirrhosis. Two adjacent duodenal pouches immediately cephalad to the orifices of the bile and pancreatic ducts opened into the duodenum through separate but similar orifices about 0.6 cm. in diameter and extended medially into the head of the pancreas. The bile duct traversed the fold of mucosa separating the diverticula and opened into the duodenum apart from the main pancreatic duct.

Specimen 2. This presented a pouch about 1.8 cm. cephalad to the major papilla, 1.25 cm. in diameter and buried to a depth of about 1.8 cm. in the head of the pancreas.

Specimen 3. This pouch was similar to specimen 2 and lay 1.25 cm. cephalad to the major papilla, approximately 0.6 cm. deep and 0.6 cm. in breadth. The walls of all of these sacs consisted of merely mucosa enveloped in loosely arranged connective tissue.

Candy ('00) reported one specimen. Cause of death, strangulated hernia. Nine centimetres caudal to the major papilla a saccular diverticulum opened into the dorso-cephalic surface of the third portion of the duodenum through a circular orifice 1.0 cm. or 1.2 cm. in diameter. The depth of the diverticulum was 1.5 cm. the fundus being located at the caudal border of the pancreas. The wall of the sac was composed of a thin layer of mucosa devoid of folds and of a thin layer of connective tissue.

LeRoy ('01) mentioned one specimen. Female, 64, emaciated. This exhibited a cancer of the major duodenal papilla in association with a diverticulum. Dorsal to the papilla a spherical diverticulum 1.1 cm. in diameter and 1.0 cm. deep opened into the duodenum through a circular orifice 0.9 cm. in diameter limited by a mucosal fold. The wall

of the sac was composed of a much-thinned mucosa and a layer of connective tissue. The muscularis spread out in a thin layer over the fundus of the sac, which did not penetrate the pancreas.

Hodenpyl ('01) presented two cases of multiple spurious diverticula of the intestine. In the first, the duodenum and the upper portion of the jejunum were the seat of a number of thin-walled cysts varying in size from that of a pea to that of an egg. Apparently no diverticula were found in the duodenum of the second specimen.

Keith ('03) figured a case of ptosis of the pancreas from the London Hospital Medical College Museum. Traction upon the common bile duct had apparently been the factor in producing a diverticulum of the duodenum at the major papilla. No further description was given.

Dorrance ('08) mentioned a diverticulum 3.5 cm. caudal to the orifice of the bile duct. The cavity measured 3.0 cm. in depth by 5.0 cm. in circumference. The walls were composed of thin mucosa and of a very thin layer of circular muscle.

Bassett ('08) reported a specimen in a male, white, aged 78, who had died of epithelioma of the lower lip. On the medial wall of the duodenum 10.0 cm. caudal to the pylorus a diverticulum extended 2.0 cm. cephalically and medially along the medial surface of the bile duct into the head of the pancreas. The orifice, somewhat smaller than the fundus of the sac, measured 2.0 cm. in the long axis of the gut and 1.0 cm. transversely. The bile duct traversed the lateral lip, opening finally at the caudolateral angle of the orifice. The mucous lining of the pouch was atrophic, degenerated, and infiltrated in places with small round cells, the duodenal glands being absent. The muscularis ended abruptly at the orifice; over the fundus the parietes consisted of mucosa alone.

Another specimen. Male, white, 78, miliary tuberculosis. This sac-like diverticulum penetrated the head of the pancreas from the median wall of the duodenum 10.0 cm. caudal to the pylorus, 3.0cm. cephalad and 2.0 cm. medial to the opening of the bile duct. The rounded orifice measured 1.5 cm. in the long axis of the duodenum by 1.0 cm. transversely. Mucosa and submucosa, much folded and containing isolated bits of pancreatic tissue, composed the wall of the sac. The muscularis of the duodenum ended abruptly at the orifice of the diverticulum.

Jackson ('08) described a diverticulum of unusual proportions springing from the transverse portion of the duodenum in a male, aged 50, who had died of pneumonia. The fundus of the sac lay dorsal to the head of the pancreas and extended cephalically a distance of 3.5 cm., measuring 3.0 cm. transversely by 2.0 cm. ventro-dorsally, and communicated with the cephalic wall of the duodenum through an orifice about 5.0 cm. in diameter. There was no relation of the sac to the ducts of the pancreas. The wall of the diverticulum consisted of mucosa, a greatly hypertrophied muscularis mucosae, and a rudimentary muscularis.

Summing up, then, we may say that exclusive of the Hansemann and Hodenpyl specimens, above mentioned, and of the

Cornell series, there are reports of only 67 specimens of duodenal diverticula available in the literature. We believe, however, that this does not represent the frequency with which these anomalies occur in the dissecting room. Many elude observation, others are noted but not reported, and again some are mentioned in papers under irrelevant headings and consequently are with difficulty collected from the literature. Schroeder, commenting upon the Fleischmann series in 1854, remarked that there were in the Fleischmann museum so large a number of duodenal diverticula as to lead one to draw the conclusion that these anomalies were found more frequently in the duodenum than in the remainder of the intestine. Apparently, this completed series, however, was never described. In this connection it is of interest to note that the sac in several of these specimens lay ventral to the head to the pancreas, a condition rarely seen by other observers. Schüppel, as noted before, found seven instances among 45 specimens examined, but in Kiel among 200 bodies examined with this end in view, he found only one diverticulum. Fairland and Calder both wrote of instances of duplication of the duodenum which might be considered as diverticula very much elongated.

Much has been written concerning the etiology of these various forms of diverticula. There has been little question over the causative factors which have produced the Meckel's diverticulum of the adult, but the so-called 'acquired' diverticula have been the occasion of much controversy. 'False' diverticula, which belong to the class of 'acquired' diverticula, possess no musculature in their walls. These have been regarded by Seippel either as a hernia of the mucosa between the muscle fibres of the intestinal wall or as a localized bulging of the intestinal wall with a subsequent atrophy of that portion of the muscularis overlying the fundus of the sac thus produced.

As causative factors in the instance of 'true' and of 'false' 'acquired' diverticula, fatty degeneration of the muscularis, atrophy of the pancreas, and ptosis of the duodenum have been advanced by Roth, Jach, Keith, and others. Instances of the production of diverticula through traction upon the duodenal

wall have been cited by Hansemann, Birsch-Hirschfeld, Klebs, and others. Increase in pressure from intestinal contents, liquid or gaseous, has been cited and diverticula have been experimentally produced in animal cadavers from these causes by Klebs, Edel, Heschl, Good and Hanau, and Hansemann. These authors noted, further, that in the instance of experimentally produced herniae of the mucosa, the seat of hernia was almost invariably at the point of entrance or emergence of the blood vessels, particularly the veins. Since these results were more readily obtained in old marasmic subjects, the conditions found in the majority of diverticula reported were thus apparently verified as, at least, contributing factors. Chlumsky experimented upon the living animal bowel and found, contrary to the results previously obtained with dead intestines, that the rupture generally occurred at some point opposite the mesentery. The traction effect of an accessory pancreas has received considerable attention and several observers have reported instances where apparently this condition was the sole etiological factor, *i.e.*, Zenker, Neumann, Weichselbaum, Nauwerck, Hansemann, and others. Fleischmann says that the production of diverticula at the major duodenal papilla is favored by reason of the weakening of the duodenal wall at the point of passage of the common bile and pancreatic ducts through the muscularis.

In a paper upon the accessory pancreatic duct and the minor duodenal papilla soon to appear, the author remarks that in 60 instances among 100 specimens of duodenum and pancreas examined, there existed at the major duodenal papilla a distinct hollowing of the duodenal wall, the papilla with the orifices of the common bile and main pancreatic ducts in these cases being situated in this depression. This condition is suggestive either of a persistence of the original diverticulum from which the liver and the ventral anlage of the pancreas developed, or illustrates the traction effect of the ducts upon the duodenal wall. Possibly, then, these specimens of so-called 'true' 'acquired' diverticula are in reality "congenital" to the extent that they represent a develop-

ment dating back to the time of hollowing of the duodenal buds in the formation of the ducts of the liver and pancreas.

In a majority of the specimens reported in the literature, the descriptions are so meagre that a complete analysis of the series cannot be made. The following interesting facts, however, may be presented. This tabulation includes the Cornell series.

Total number of duodenal diverticula.....*83*

In addition to this number Hansemann reported one duodenum with several diverticula and Hodenpyl two duodena, one with several diverticula. In the other, the latter did not state clearly whether there were any duodenal diverticula.

Eliminating the Hansemann and the Hodenpyl specimens from the series and considering that the 8 in the Schüppel series were single, *i.e.*, one diverticulum in each duodenum, we may, with the restrictions mentioned above classify the diverticula as follows:

Doudena presenting:

One diverticulum	48	Two diverticula	9
Three diverticula	0	Four diverticula	3
Five diverticula	1		
Total number of duodena (including Hansemann's and Hodenpyl's)	63		

Sex

Males	21	Females	14	Not given	28

Age

Available in 30 instances	Youngest 22 (female)	Oldest 85 (male)	
Two others were reported as 'aged.'			

Condition of cadaver

'Emaciated'	7	'Lean'	5	'Medium'	5

Constituents of wall of diverticulum

With muscularis	20	Without muscularis	16	No report	47

Position of fundus of diverticulum

Ventral to pancreas head	Several of Fleischmann series (see above)
Penetrating pancreas head	17
Dorsal to pancreas head	14
The remainder projected towards but not into the head of the pancreas.	

Location of diverticula

Convex side of duodenum		0
Concave (pancreas) side of duodenum		72
Specimens not described in full	Schüppel	8
	Letulle	1
	Hansemann	(?)
	Hodenpyl	(?)
	Good	2
Near pylorus		5
At minor papilla		9
With accessory duct opening into diverticulum		1
Near major papilla		12
At major papilla		24
Bile duct opening into diverticulum		4
Main pancreatic duct opening into diverticulum		3
(In one of these the duct was occluded).		
Bile and pancreatic ducts together opening into diverticulum		4
Diverticulum in third portion of duodenum		12

In conclusion I may say that it is a genuine pleasure for me hereby to express my sincere appreciation of the helpful advice given by Professors Gage and Kerr in the preparation of this paper and also of the numerous and great courtesies shown by the departments of Anatomy and of Histology and Embryology.

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PLATE 1

EXPLANATION OF FIGURES

4 This sketch, made from the actual specimen, represents the duodenal mucosa with the mouth of the diverticulum. The duodenum was opened along that border opposite to the orifice of the diverticulum.

5 In this diagram the diverticulum shown in fig. 4 is represented as seen from the dorsum. The fundus is represented projecting cephalically from the third portion of the duodenum and lying dorsal to the head of the pancreas.

6 This natural-size sketch represents the doudenal mucosa with the orifice of the diverticulum. The duodenum was opened opposite to the site of the diverticulum. Note the close relation of the orifice to the major duodenal papilla.

7 In this diagram the dorsal surface of the head of the pancreas is shown encircled by the duodenum. The fundus of the sac represented in fig. 6 is seen projecting in close proximity to the bile duct and dorsal to the head of the pancreas.

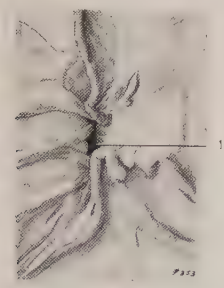
8 In this sketch the mucosa lining the interior of the diverticulum can be seen. Just within the orifice and running cephalo-caudally across the dorsal wall of the sac a prominent fold of mucosa is seen presenting on its summit caudally the major papilla. This diverticulum is the largest yet described.

9 In this sketch the close relation of the orifice of the diverticulum to the major duodenal papilla is represented.

10 This diagram presents the relation of the fundus of the diverticulum, represented in fig. 9, to the dorsal surface of the head of the pancreas and especially to the bile and pancreatic ducts.

REFERENCE NUMBERS

1 Orifice of diverticulum.
2 Duodenum (dorsal aspect).
3 Head of pancreas (dorsal aspect).
4 Diverticulum.
5 Major duodenal papilla.
6 Ductus choledochus.
7 Mucosal fold.
8 Ductus pancreaticus.



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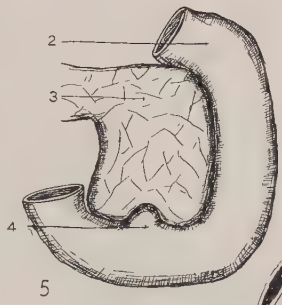

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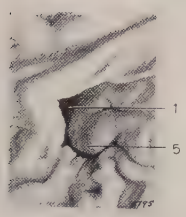

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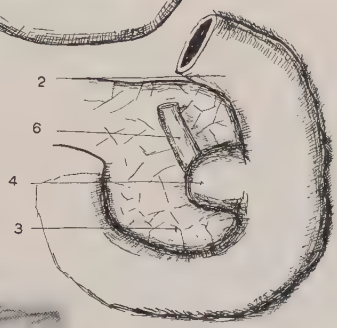

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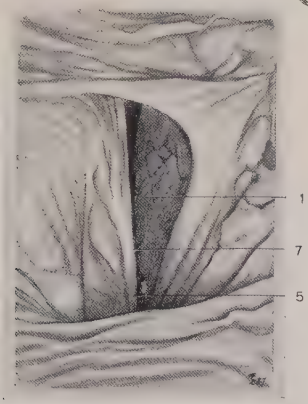

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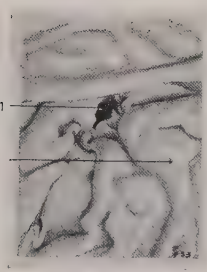

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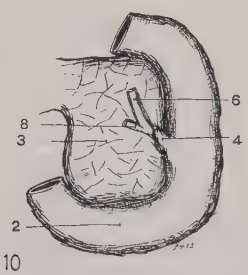

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PLATE 2

EXPLANATION OF FIGURES

11 This sketch resembles in general appearance fig. 8. The fold of mucosa traversing the dorsal wall of the sac bearing the major duodenal papilla is well shown. These structures lie just within the orifice of the diverticulum.

12 This sketch shows the close relation of the orifice of the diverticulum to the major duodenal papilla.

13 This diagram shows the relation of the diverticulum, represented in fig. 12. to the dorsal surface of the head of the pancreas and to the bile and main pancreatic ducts.

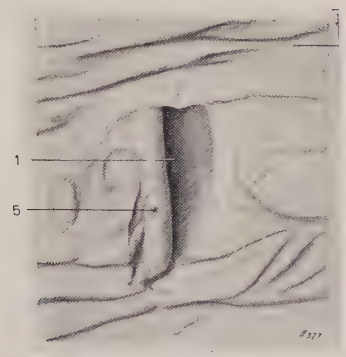
14 In this sketch the common orifice of the diverticulum, the bile, and the main pancreatic duct is shown upon the mucosa of the second portion of the duodenum.

15 This sketch shows the orifice of a diverticulum situated in the third portion of the duodenum.

16 In this diagram the fundus of the diverticulum, represented in fig. 15, is shown in relation to the dorsal surface of the head of the pancreas. There is, of course, no relation to the bile or pancreatic ducts.

REFERENCE NUMBERS

1 Orifice of diverticulum.
2 Duodenum (dorsal aspect).
3 Head of pancreas (dorsal aspect).
4 Diverticulum.
5 Major duodenal papilla.
6 Ductus choledochus.
8 Ductus pancreaticus.



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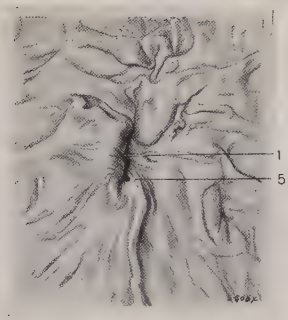

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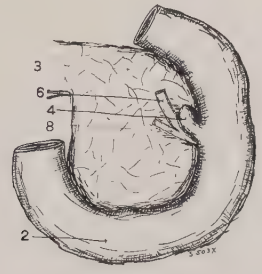

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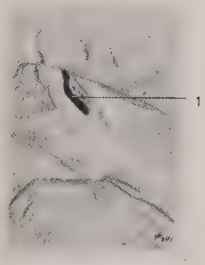

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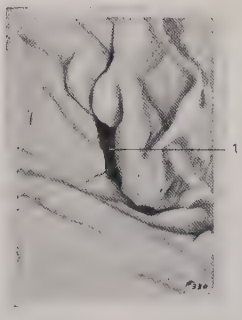

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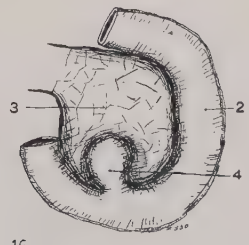

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PLATE 3

EXPLANATION OF FIGURES

17 This sketch represents the duodenal mucosa exposed to show the orifice of the diverticulum.

18 In this diagram the head of the pancreas encircled by the duodenum (fig. 17) is represented as viewed from the dorsum. The fundus of the diverticulum located at the duodenal-jejunal flexure is shown in relation to the pancreas.

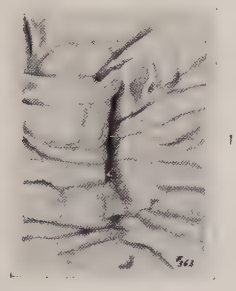
19 In this sketch the orifice of the diverticulum lies immediately cephalic to the major duodenal papilla.

20 This diagram represents the relation of the fundus of the diverticulum, shown in fig. 19, to the bile and main pancreatic ducts and to the dorsal surface of the head of the pancreas.

21 In this sketch the orifice of the diverticulum is shown upon the mucosa of the third portion of the duodenum.

REFERENCE NUMBERS

1 Orifice of diverticulum.
2 Duodenum (dorsal aspect).
3 Head of pancreas (dorsal aspect).
4 Diverticulum.
5 Major duodenal papilla.
6 Ductus choledochus
8 Ductus pancreaticus.



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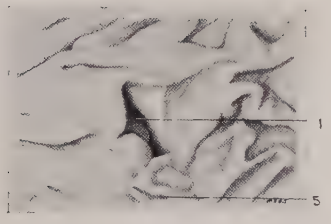

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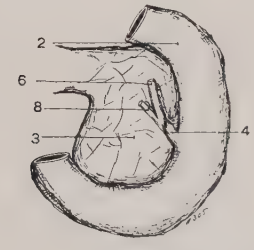

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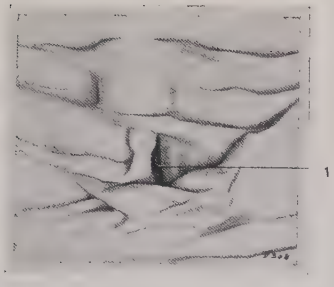

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PLATE 4

EXPLANATION OF FIGURES

22 In this sketch the relation of the small tubular diverticula to the minor duodenal papilla is seen.

23 This sketch represents the mucosa of the third portion of the duodenum with the orifice of the diverticulum.

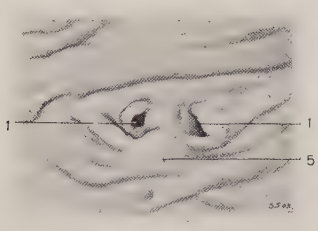
24 In this diagram the fundus of the diverticulum, represented in fig. 23, is shown as seen from the dorsum. The fundus extends cephalically lying dorsal to the head of the pancreas but it has no immediate relation either to the ducts of the pancreas or to the bile duct.

25 In this sketch a large diverticulum is represented opening into the third portion of the duodenum.

26 This diagram represents the fundus of the diverticulum, shown in fig. 25, as seen from the dorsum. It lies dorsal to the head of the pancreas but has no relation to the ducts of the gland or to the bile duct.

REFERENCE NUMBERS

1 Orifice of diverticulum.
2 Duodenum (dorsal aspect).
3 Head of pancreas (dorsal aspect).
4 Diverticulum.
5 Minor duodenal papilla.



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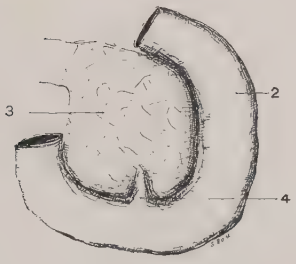

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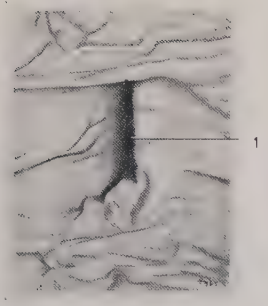

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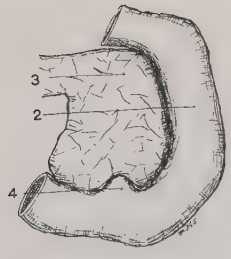


26

AN UNUSUALLY LARGE PERITONEAL FOSSA

MESENTERICO-PARIETAL

T. D. MERRIGAN

Professor of Anatomy at Fordham University

ONE FIGURE

The pouching of the peritoneum into more or less well marked fossae has from time to time received the attention of anatomists and surgeons as possible sites of intraperitoneal herniae.

Anatomists have found about a dozen localities in which this pouching may occasionally be found.

Moynihan has pointed out the rare occurence of a pouching behind the superior mesenteric artery; between it and the posterior abdominal wall. This fossa on account of its rarity is not mentioned in the great majority of works on anatomy.

The speciman here reported was discovered in the dissecting room of Fordham University. It has been preserved and is at present in the museum of the medical school.

The arrangement of the peritoneum was found to be as follows: The portion of the transverse mesocolon to the right of the superior mesenteric artery passes downward to become the anterior wall of the sac. To the left of the superior mesenteric artery the transverse mesocolon passes to the posterior abdominal wall being continuous on the left with the inner layer of the decending mesocolon and mesosigmoid; to the right it passes across the spinal column in front of the aorta and vena cava, to the right side as far as the attachment of the ascending colon to the posterior abdominal wall; here it is reflected to the inner surface of the anterior wall of the pouch.

At the upper part of the posterior abdominal wall as the peritoneum crosses the spinal column as described, it invests about

three-quarters of the circumference of the transverse duodenum as it appears from beneath the ascending colon from the right side of the third lumbar vertebra; this investiture is about an inch in extent. From the right of the median line of the spinal column and extending obliquely up to the left the remainder of

the duodenum has a distinct mesentery measuring about one and a half inches in width (from the attached margins of the gut) and extending beneath the superior mesenteric artery and becoming continuous with the mesentery of the jejunum; so that, the mesentery in this subject actually begins on the right side of the median line between the second and third lumbar vertebra, ex-

tends obliquely upward to the middle of the body of the second lumbar vertebra, forming the suspensory ligament of part of the transverse duodenum and the beginning of the jejunum.

The superior mesenteric artery comes from beneath the pancreas in front of the second lumbar vertebra to enter this short mesentery and lies beneath the upper part of the left border of that portion of the descending mesocolon which forms the outer layer of the anterior wall of the sac.

The artery extends obliquely downward toward the right, to the last part of the ileum a short distance from the ileocecal junction forming as far as its ileocolic branch the beginning of the anterior border of an arched recess or niche with its opening to the left. The lower part of this anterior border is completed by a well defined peritoneal fold containing the origin and course of the ileocolic artery. The floor or the posterior wall of the recess extends downward on a line from the front of the body of the second lumbar vertebra to a point about opposite the right sacro-iliac synchondrosis where it becomes continuous with the lower end of the anterior border of the opening and the peritoneum on the left side of the meso-appendix; to the right it extends as far as the ascending colon and upward as far as the transverse mesocolon. Projecting into the floor of the upper part of the recess is the beginning of the transverse duodenum partly invested by peritoneum as previously stated.

The exterior surface of the arched roof of this recess or niche, formed by that portion of the descending layer of the transverse mesocolon to the right of the upper part of the superior mesenteric artery and to the right of the origin and course of its ileocolic branch and forming the exterior layer of the thin anterior wall of the hernial sac, extends to the right as far as the attachment of the ascending colon to the posterior abdominal wall, to become continuous with the inner layer of the ascending mesocolon.

The contents of the sac when withdrawn consists of loops of jejunum and ileum which are attached to the branches given off from the left side of the superior mesenteric artery.

These branches are contained in the extra peritoneal areolar tissue enclosed between the layers of the peritoneum which are reflected over the jejunum and ileum in the same manner as the peritoneum of the normal mesentery.

The width of this structure (containing two layers of peritoneum, between which are the mesenteric branches, areolar tissue, fat, glands, lacteals, etc.) from the superior mesenteric artery and its ileocolic branch to the attached border of the intestine varies from two to four inches and appears as an exaggerated fringe or ruching attached to the anterior border of the recess.

This structure with the intestine is rolled under the anterior border of the opening to fill the pouch. The ascending colon is nourished by the ileocolic and a loop formed by a branch from its right side which passes upward on the right side of the anterior wall of the sac at a distance of about one inch from the ascending colon. This loop anastomoses with a very small colica dextra artery which runs obliquely across the anterior wall of the sac between its exterior and interior layer of peritoneum and the well developed right branch of the colica media artery which runs, in the border formed by the sac and the descending layer of the transverse mesocolon.

The size of the mouth of the opening from the centre of the arched anterior border to the posterior abdominal wall measures three inches. From above downward along the posterior abdominal wall the opening is five and a quarter inches.

The jejunum and ileum at the mesenteric border measures about ten feet and with the exception of about eighteen inches of the terminal portion of the ileum is contained in the sac.

BLACK TOPS FOR LABORATORY TABLES

PIERRE A. FISH

Ithaca, N. Y.

In 1903 I published a short article in the Journal of Applied Microscopy, vol. 6, no. 3, pp. 2211–2212, under the title of "An Acid-Proof Table Top." Attention was called in that article to the fact that a formula for blackening the tops of tables had been observed in a pharmaceutical journal, but that the author's name was not printed.

The formula was modified by the present writer and has since been largely used by Professor S. H. Gage and others. It was given to a local cabinet maker in order that the furniture for our laboratories might be finished completely before delivery. I am informed by him that he has used it extensively on other laboratory furniture, shipped to various points, and that it has apparently given general satisfaction.

The writer has received numerous inquiries regarding the modified formula and since the journal in which it was originally printed is no longer published, the revised formula is herewith given for the benefit of those who may be interested in it:

Solution 1

	PARTS
Iron sulphate	4
Copper sulphate	4
Potassium permanganate	8
Water	100

This mixture is thoroughly boiled in a kettle of iron or some other metal and applied while hot. Two coats should be applied. The first should be allowed to dry before the application of the second. The excess of chemicals upon the surface should be thoroughly dusted or rubbed off before applying the next solution.

Solution 2

	PARTS
Aniline	12
Hydrochloric acid	18
Water	100

These chemicals should be put in a glass vessel, the water being added first. No heat is required for this solution; but as before, two coats should be applied, the second being put on after the first has become dry. The surface should be washed and well scrubbed with hot soapy water, followed by a rinsing with clear water.

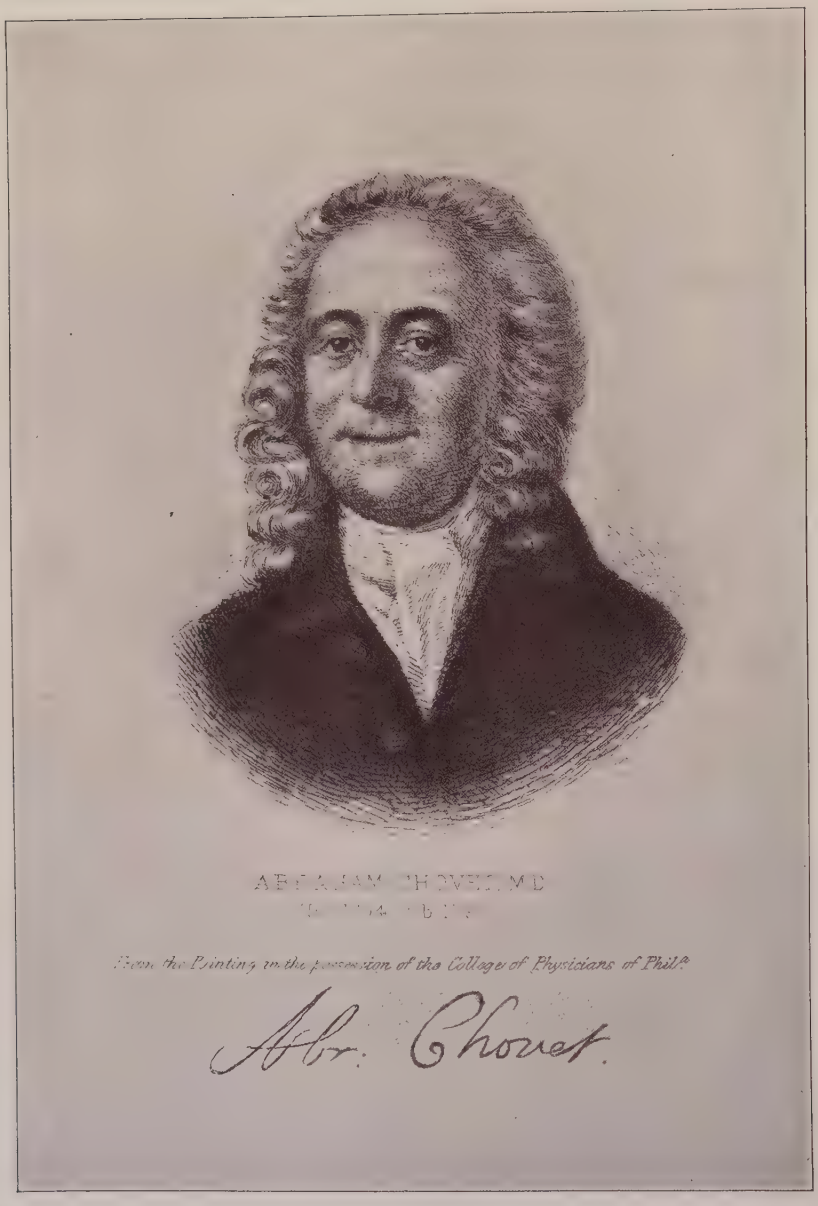
The third solution consists of equal parts of linseed oil and turpentine well rubbed in. It is no disadvantage to apply this solution hot, but very good results are obtained when applied cold.

The black color may not be marked at first, it is often of a dirty green appearance, but this soon gives way to an ebony black.

Subsequent cleaning, at the end of the laboratory courses, may be accomplished by washing with soap and water and when this is dry by applying the turpentine-oil mixture.

This method may be applied to old tables, but it is essential that the old finish—varnish or wax—be entirely removed, down to the fresh wood, either by planing or the use of a caustic potash solution.

Professor Gage, in describing this method in his work on the Microscope ('04), states that it is sometimes called the Danish method or Denmark black finish. He also gives the following references: Jour. Ap. Micr., vol. 1, p. 145; Bot. Zeit., vol. 54, p. 326; Bot. Gazette, vol. 24, p. 66; P. A. Fish, Jour. Ap. Micr., vol. 6, pp. 2211–2212.



From the etching by Rosenthal

ABRAHAM CHOVET: AN EARLY TEACHER OF ANATOMY IN PHILADELPHIA[1]

WILLIAM SNOW MILLER

From the Anatomical Laboratory of the University of Wisconsin

SEVEN FIGURES AND TWO PLATES

Some time since, while looking up the history of the use of corrosion preparations and models in the teaching of anatomy in the United States, I came across the following, written by John Morgan, of Philadelphia, in 1786:

> Such is the present state of anatomy in this country that there are at present but few, I believe I may say no such preparations worth mentioning to be met with here, that have been made in America. Dr. Chovet, now a resident in this City has indeed a good collection of wax preparations, of different parts of the human body, which he made in his younger days and brought hither from Europe. But nothing of this kind has hitherto been practiced or has been so taught as to have been of lasting use to any that I know of.

The question at once presented itself: Who was Dr. Chovet: what were the 'preparations' mentioned and what became of them?

For the past two years I have devoted considerable time to an attempt to answer this question and I am compelled to state that the answer to the first part of the question is in a great measure unsatisfactory and that the answer to the second part is also, though in a different sense, equally unsatisfactory.

Of the early life and education of Chovet we know but little. On the back of the frame of a miniature which was presented to the Pennsylvania Hospital there is deeply scratched, "Abraham

[1] Read before the Johns Hopkins Hospital Historical Club, December 12, 1910.

Chovet, born May 25, 1704." Who his parents were, the place of his birth and his nationality, I have been unable to ascertain. In a footnote, Ruschenberger says the name "is not French but an English patronymic; one of a class of two syllable names ending in *et* or *ett*, as Cobbett, Collet, Levet." Against this statement may be placed the fact that he was bound to Peter Gongoure le marque; this would seem to give some support to those who claim he was of French descent.

George W. Norris in The Early History of Medicine in Philadelphia says, "He was a native of England, and devoted much of the early part of his life to the study of anatomy under the ablest teachers in Europe." Chastellux gives England as his native country and goes on to say that, "after studying medicine and surgery there, he went to France to improve himself under M. Winslow."

Thirty years elapse between the date of his birth and the time when we find any definite information in regard to Abraham Chovet. The few meagre notes I have been able to get together must suffice for this period of his life. This much is certain: in some manner Chovet acquired sufficient knowledge of anatomy to be appointed demonstrator of anatomy in The Worshipful Company of Barber-Surgeons of London.

For many of the facts connected with Chovet and the Barber-Surgeons I am indebted to Sidney Young, F.S.A., Past Master of The Worshipful Company of Barbers of London, and author of The Annals of the Barber-Surgeons of London. Finding the notes in the annals insufficient, he most kindly made transcripts of such minutes as he thought of interest and placed them at my disposal.

Extracts from the Records of the Worshipful Company of Barber-Surgeons of London

At a Court of Examiners holden 5th Fbry. 1734. (present Mr. James Ferne, Master, Mr. Barnwell, Mr. Bridges, Mr. Watts, Wardens, Mr. Myddleton, Mr. Petty, Mr. Wheeler).

Abraham Chovett S (urgeon) who had been bound to Peter Gongoure le marque a Foreign Brother of the Company, was Examined touching

his skill in Surgery in order to be admitted a Foreign Brother. His answers were approved and he was ordered a diploma under the seal of the Company, admitting him as such for Three pounds three shillings, which he paid down and was sworn a Foreign Brother of the Company.

At a Court of Assistants holden 6th Aug. 1734. Mr. Abraham Chovett Surgeon and a Foreign Brother took up his freedom of the Company for Three pounds three shillings which he paid down and was sworne, and then the said Mr. Chovett took the Livery and Clothing of the Company and gave his note for the usual fine of Ten pounds.

In the Annals of the Barber-Surgeons the following entry appears: "15th August, 1734. Mr. Abraham Chovett and Mr. Peter Maccullock were chosen Demonstrators of Anatomy." It is quite probable that the full entry for August 15th, 1734, was the same as that of the following year:

At a Court of Assistants holden 21st August 1735. Then the Court . . . . did appoint Mr. Abraham Chovett and Mr. Peter Maccullock Demonstrators of Anatomy for the year ensuing. And it is ordered that each of them shall have the Dissecting of one Publick and one Private body and shall not interfere with each other otherwise than to assist each other for the Publick Service.

It is ordered that the Demonstrators for the time being shall be invited to all the Publick Feasts of the Company when the Masters and Stewards of Anatomy are invited.

It is to be noted in the entries of February 5, 1734, and of August 6, 1734, that Chovet is described as a 'Foreign Brother.' This did not necessarily mean he was a foreigner or alien in the modern acceptation of the word, but a surgeon who practiced within the jurisdiction of the Company of Barber-Surgeons of London and was not 'free' of the Company by patrimony, servitude or redemption. Peter Gongoure le marque was, as his name would imply, a genuine foreigner practicing in London and so compelled to become a Foreign Brother of the Company or be debarred from practicing.

In a private letter Sidney Young writes me as follows:

You will notice that on 6th Aug. 1734, Chovett came into our Guild and took up his "freedom" by redemption and then the higher grade of the 'Livery.'

I should think that he did this with the knowledge that on the 15th of the same month he was to be chosen Demonstrator of Anatomy and it was considered desirable that such an important office should be held by a Liveryman and not by a mere 'F. B.' The 'Publick body' referred to in the minute of 21, Aug. 1735, would be that of a criminal executed for felony which our Company gave out of the stock of those unfortunates of whom we had a plenty, and Chovett would be allowed that body to experiment upon before his own class of students (and not before the Surgeons and their apprentices within the Company).

The 'Private body' would be one obtained from the Resurrectionists and used for the same purpose. These were special privileges granted to the Demonstrators of Anatomy by the Court.

Chovet must have given lectures on anatomy previous to his appointment as demonstrator of anatomy in the Barber-Surgeons Company, for we find that in the year 1732, he issued A Syllabus, or Index of all the Parts that enter the Composition of the Human Body. This was a small brochure of 26 pages, the title page of which is reproduced in fig. 1.

It is quite propable that on account of his success as a lecturer on anatomy and the issuing of his Syllabus he was invited to join the Barber-Surgeons and become one of their demonstrators. In one of his letters to me Sidney Young says: "I should think from his position and his residing in Leicester Square, that he must have been an eminent surgeon of the time."

In another letter he again refers to Chovet, "as living in Leicester Square which at that time was the fashionable locality for surgeons in large practice."

The influence of the French school is shown in the preface to his Syllabus. He speaks of their being "fruitful in their inventions" and in contriving "anatomical preparations made in wax," which he endeavored to improve. This seems to confirm the statement, made by Chastellux, that he studied under Winslow.

A

SYLLABUS,

OR

INDEX,

Of all the

PARTS that enter the Compoſition of the HUMAN BODY:

In Twelve LECTURES.

For the Uſe of Thoſe that go through

COURSES of *ANATOMY.*

By ABRAHAM CHOVET, *Surgeon.*

PSALM CXXXIX. *Ver.* 14.

I will praiſe THEE, *for I am fearfully and wonderfully made.*

221.

LONDON:

Printed for the AUTHOR.

M. DCC. XXXII.

Fig. 1 Title page of the Syllabus.

Their Division.

The Small Guts 3, *viz.*
Duodenum,
Jejunum,
Ileum.

Large Guts 3 *also, viz.*

The Colon, where there is a Valve
Use of the Valve,
Cæcum,
Rectum.

Of the Mesentery.

Its Glands,
Connexion,
Vessels,
Use.

Of the Lacteal Vessels, Receptaculum Chyli, and Ductus Thoracicus.

The Vasa Lactea Primi Generis,
Vasa Lactea Secundi Generis,
Receptacle in Brutes,
Thoratick Duct,
Their Situation and Use.

Prælectio Octava.

Of the Liver, Pancreas, Spleen, Urinary Parts, and the Organs of Generation of both Sexes.

The Liver.

Ligaments Suspensorium,
Latum,
Umbilicale.

Its Coats,
Gall Bladder.

Excretory Ducts Cystihepatici,
Cysticus,
Hepaticus,
Communis Choledochus.

Vessels Vena Porta,
Vena Cava,
Arteria Hepatica.

The Pancreas,

Its Coats,
Vessels,
Excretory Ducts, *&c.*

The Spleen,

Its Coats,
Vessels,
Substance, *&c.*

Fig. 2 Page 20, of the Syllabus.

The last page of the preface is of so much interest that I will quote the greater part.

> I have likewise contriv'd a body in wax (now in hand) wherein the action of the heart and lungs, and the circulation of the blood, will be made visible, which I hope in some time to compleat.
>
> I am also provided with natural and artificial preparations sufficient for giving a compleat course of anatomy, which will be of great use to young beginners for the first course, in order to prepare them for the knife; as also those who are willing to be informed in the natural structure, tho' not devoted to the practice of physic or surgery, and are often times offended at the smell and sight of a dissected body, for which reason I have compiled this Syllabus as brief and suitable thereto, and as much in English as the nature of the subject will permit, avoiding many superfluities.

Here we see Chovet putting into practice a principle that many of the modern teachers of anatomy advocate: that of studying models and moist preparations before beginning the actual dissection. In this way the student obtains an idea of what he is to look for when working on the cadaver.

The similarity in the wording of the announcement of his lectures in Philadelphia (p. 160, fig. 7) to the closing paragraph of the preface of his Syllabus is striking and shows that he still has in mind the same educational principle.

The Syllabus is divided into three parts; the first is Osteologia, and is covered by the first three lectures; the second is Myologia, and also extends over three lectures; the third is Enterologia, and occupies the remaining six lectures.

The page of the Syllabus that is reproduced (fig. 2) shows the attention that the lymphatic system received in those days. It is to be regretted that in these days of advanced anatomy it receives so little attention in many dissecting rooms. When he considers the heart and lungs, he also considers the circulation of the blood.

His knowledge of the anatomy of the brain was quite comprehensive, as the following extract from his Syllabus shows.

Dura Mater
Its First Process, the Falx
Second Process
Third Process
Sinus's
The Longitudinalis Superior
Inferior
Rectus
Latteralis, etc.
Torcular Herophili
Pia Mater
Cerebrum
Hemispheres, 2
Lobs,4
The Carotide Arteries
Cervicals
Glandula Pittuitaria
The Substances 2 viz.
Corticalis Cineria
Meddularis Alba
Centrum Ovale
Corpus Callosum
Fornix
Septum Lucidum
Medulla Oblongata
The Crura
Ventriculi Anteriores, with the 3d and 4th
Corpora Striata
Thalami Nervorum Opticorum
Nates
Testes
Glandula Pinealis
Plexus Choroides
Corpora Olivaria
Protuberantia Annularis

In his enumeration of the cranial nerves he shows that he, like most of his contemporaries, failed to recognize the true VIth pair of nerves. He lists ten pairs of nerves, as follows:

1st Par Olfactorium
2d Opticum
3d Oculorum
4th Patheticum
5th Gustatorium
6th Produce the Intercostals
7th Auditorium
8th Vagum
9th Accessorius
10th Recurrens

If, as Chastellux states, Chovet was a student under Winslow, it is somewhat surprising that he failed to recognize the true character of the 'intercostals' and ascribed them to the VIth pair of cranial nerves and not to the sympathetic nerve. In his description of the sympathetic nerve Drummond says:

This nerve has been variously named by authors. The older anatomists described it under the name of the great intercostal nerve. From the fact of its being chiefly distributed to the viscera belonging to the

circulatory, digestive and generative systems, it was termed by Chaussier the trisplanchnic nerve; and under the supposition that it alone influences the organic processes, it was termed by Bichat the nervous system of organic life. The name sympathetic, or great sympathetic, was given it by Winslow, from its being believed to be the channel through which are effected the different sympathies sometimes found to exist between distant organs when in a morbid condition.

The English anatomists did not seem to agree with Winslow for Monro and Cheselden followed Chovet in ascribing the intercostals to the VIth pair of nerves. It was not until the time of Bell that they began to recognize their mistake.

The last page of the Syllabus contains so much of interest that I have reproduced it in full (fig. 3). Here we see evidence of a great amount of industry on the part of Chovet and can gain some conception of the way he spent his time during the period of which I have been unable to find any record. It also gives us a new insight into the method of teaching anatomy in the middle of the eighteenth century. Models and carefully prepared preparations supplemented demonstrations on the cadaver. Surely Chovet had advanced ideas of anatomical study.

In 1736, Chovet resigned his position as demonstrator.

At a Court of Assistants holden 19th Aug. 1736. Our Master acquainting the Court that he had received a letter from Mr. Chovett wherein he expressed a just sense of the favor the Court had done him to choose him Demonstrator the two former years and returned his thanks for the same. But in regard to his other business did desire the Court would please to supply his place by the choice of some other.

Chovet's request was granted; and we find recorded in the Annals of the Barber-Surgeons under the same date: "Mr. Peter Maccullock and Mr. Caesar Hawkins were elected Demonstrators."

In a footnote to the abstracts sent me by Sidney Young he says: "Mr. Chovett's name appears in the list of Liverymen for the year 1740, but not afterwards. This is presumptive evidence that he was dead before the list for the year 1741 was made up."

A Deſcription of the ſeveral Anatomical Preparations, to be made uſe of for the Demonſtration of the Courſes, VIZ.

AN artificial Anatomy of a Boy, repreſenting on one Side all the External Muſcles in their natural Situation, as alſo the Salivary Glands, with their Excretory Ducts. In this Figure the two great Cavities of the Body are to be laid open in the Demonſtration, and their contained Parts to be removed, *viz.* in the Abdomen, the Ventricle, or Stomach, is ſeen with its Right and Left Oriſice; the Inteſtines, or Guts, with their Meſſentary and Glands; the Liver and Gaul-Bladder, the Spleen, the Pancreas, with their Excretory Ducts; underneath which Parts, when removed, are alſo ſeen the Kidnies, in their natural Situation, with their Emulgent Veſſels, Ureters, and the Bladder of Urine.

The Great Artery and Vein injected, the Artery conveying its Branches from the Heart to all the Parts of the Body, even to the ſmalleſt Capillary Veſſels, viſible to the naked Eye, as far as the Perioſteum, a fine Membrane covering the Bones, and the Capillary Veines uniting in two Trunks, return into the Heart.

In the Thorax the Lungs are ſeen inflated in their natural Situation, with the Heart and Veſſels, the Coronary Artery and Vein twining from its Base, to its Point; the Auricles, and Ventricles, and Valves at the going out and coming in of the Great Veſſels; beſides the Diophragma dividing theſe two Cavities.

The artificial Head of a Man modelled from the natural, wherein are deſcribed the Muſcles of the Pharynx, Larynx and Tongue, with the Diſtribution of the Artery, Veins and Nerve to each of them.

The Parts of Generation belonging to both Sexes, both natural and artificial.

The Fœtus in Utero, in its real Situation, and Membranes with the Placenta Umbillical Veſſels, *&c.* correctly modelled from the natural, as it was taken out of the Body of a Woman.

The real Head of a Woman, with a Heart injected.

The Body of a Man diſſected, and prepared after a new Method, wherein all the Muſcles are raiſed, and the whole Progreſs of each diſtinctly ſhewn, with all the Internals, *&c.* Beſides ſeveral other Preparations too tedious to mention.

F I N I S.

Fig. 3 Last page of the Syllabus.

How far this was from the truth the remainder of this sketch will show.

There seems to be considerable mystery surrounding the occasion of Chovet's resignation as Demonstrator in the Barber-Surgeons Company and his removal from London. S. Weir Mitchell in his commemmorative address at the centennial anniversary of the institution of the College of Physicians of Philadelphia, makes the following statement:

> Of the cynical and merry tory Abraham Chovet, there is little to say. Dr. Physick told my father that while living in London, Chovet tried to save a too adventurous gentleman about to be hanged for highway robbery, by opening his trachea before the hangman operated. The patient was rapidly removed after the execution, and is said to have spoken. A queer tale, and doubtful, but worth the telling. The government is said to have lacked due appreciation of this valuable experiment, and Chovet brought his queer Voltarian visage to America.

I have been unable to obtain any confirmation of the first statement and the last statement is not quite correct. According to Chastellux, *The Universal Asylum and Columbian Magazine* for 1790, and Norris, Chovet spent some years in the Barbadoes and afterwards went to Jamaica.

Whatever the cause of Chovet's leaving his surgical practice in the fashionable quarter of London, he did not lose his interest in anatomy. The conditions in Barbadoes were not conducive to work; yet he worked. Chastellux says he was, "invariably a man of application, and laborious. In the war of 1744, a prize being brought into Barbadoes, with a great deal of wax on board, Mr Showell (a misspelling) took this opportunity to make different anatomical experiments in wax, and succeeded so well as to carry this art to the highest perfection."

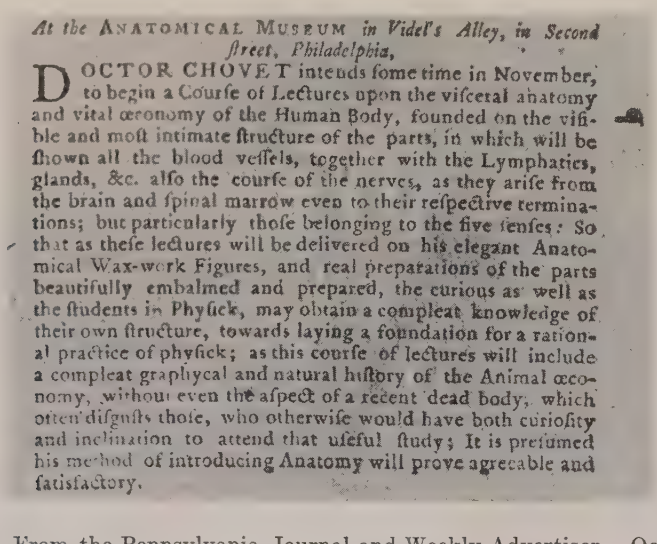
For the single authentic item I possess in regard to Chovet's life in Jamaica I am indebted to D'Arcy Power, F.R.C.S. In the *Gentleman's Magazine* for the month of May 1759, under the promotions for the year 1759, appears the following: "Abra. Chovet, Esq., surgeon, of Kingston in Jamaica, a Dr. of physick."

D'Arcy Power writes, "I cannot find that this M. D. was confered by Oxford: there is no list of Cambridge graduates and there is no list of the M. D.'s given by the Archbishop of Canterbury."

If the story narrated by S. Weir Mitchell be true, it seems strange that this degree should have been conferred on Chovet.

Jamaica was not, however, to be the final abode of Chovet. In order to escape an impending insurrection of the slaves he fled with his wife and widowed daughter to Philadelphia. The date of his arrival in Philadelphia is uncertain. In the notice of his death, in the *Universal Asylum and Columbian Magazine* for March, 1790, it is given as 1770. Norris, in The Early History of Medicine in Philadelphia, gives 1774, as the date.

Almost immediately after the arrival of Chovet in Philadelphia he began giving lectures on anatomy. In the *Pennsylvania Journal and Weekly Advertiser* for October 12, 1774, the following announcement appears



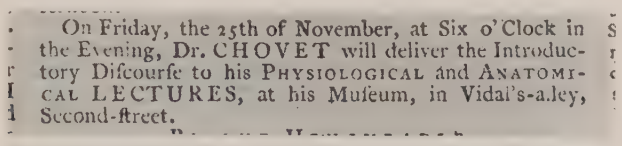
At the ANATOMICAL MUSEUM *in Videl's Alley, in Second ſtreet, Philadelphia,*

DOCTOR CHOVET intends ſome time in November, to begin a Courſe of Lectures upon the viſceral anatomy and vital œconomy of the Human Body, founded on the viſible and moſt intimate ſtructure of the parts, in which will be ſhown all the blood veſſels, together with the Lymphatics, glands, &c. alſo the courſe of the nerves, as they ariſe from the brain and ſpinal marrow even to their reſpective terminations; but particularly thoſe belonging to the five ſenſes: So that as theſe lectures will be delivered on his elegant Anatomical Wax-work Figures, and real preparations of the parts beautifully embalmed and prepared, the curious as well as the ſtudents in Phyſick, may obtain a compleat knowledge of their own ſtructure, towards laying a foundation for a rational practice of phyſick; as this courſe of lectures will include a compleat graphycal and natural hiſtory of the Animal œconomy, without even the aſpect of a recent dead body, which often diſguſts thoſe, who otherwiſe would have both curioſity and inclination to attend that uſeful ſtudy; It is preſumed his method of introducing Anatomy will prove agreeable and ſatisfactory.

Fig. 4 From the Pennsylvania Journal and Weekly Advertiser. October 12, 1774.

The same announcement appears in the issue for November 15, except the words "the 25th Nov. instant" are substituted for "some time in November."

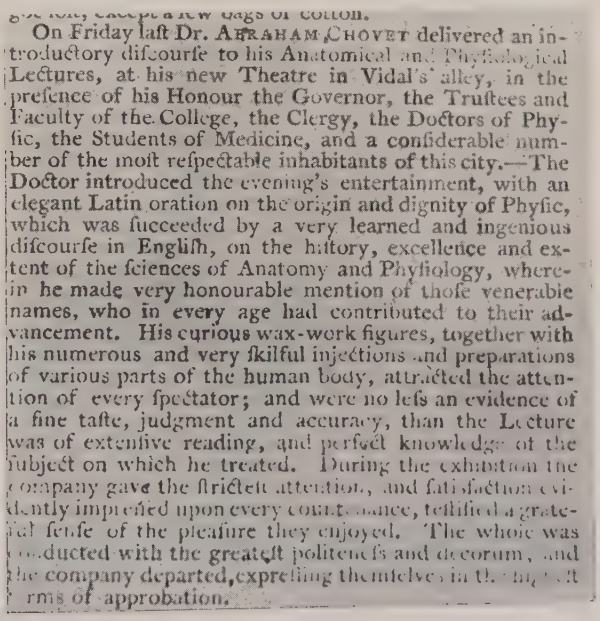
In the issue of the *Pennsylvania Journal and the Weekly Advertiser* for November 9, 1774, and in the issue of the *Pennsylvania Gazette* for the same date, the following announcement of his introductory lecture appears



On Friday, the 25th of November, at Six o'Clock in the Evening, Dr. CHOVET will deliver the Introductory Diſcourſe to his PHYSIOLOGICAL and ANATOMICAL LECTURES, at his Muſeum, in Vidal's-alley, Second-ſtreet.

Fig. 5 From the Pennsylvania Gazette. November 9, 1774.

The occasion of the introductory lecture was made a notable event, as the following account taken from the *Pennsylvania Gazette* of November 30, 1774, shows.



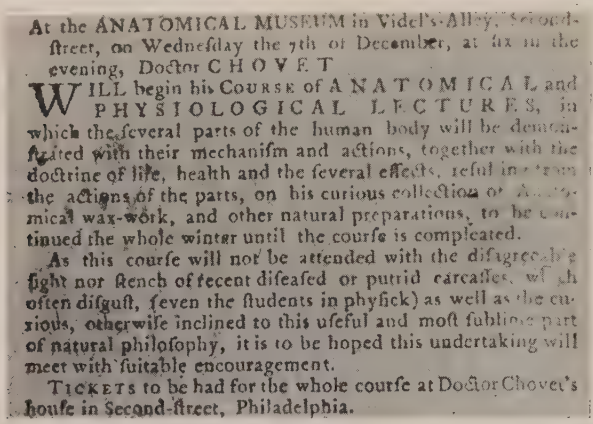
...except a few bags of cotton.

On Friday laſt Dr. ABRAHAM CHOVET delivered an introductory diſcourſe to his Anatomical and Phyſiological Lectures, at his new Theatre in Vidal's alley, in the preſence of his Honour the Governor, the Truſtees and Faculty of the College, the Clergy, the Doctors of Phyſic, the Students of Medicine, and a conſiderable number of the moſt reſpectable inhabitants of this city.—The Doctor introduced the evening's entertainment, with an elegant Latin oration on the origin and dignity of Phyſic, which was ſucceeded by a very learned and ingenious diſcourſe in Engliſh, on the hiſtory, excellence and extent of the ſciences of Anatomy and Phyſiology, wherein he made very honourable mention of thoſe venerable names, who in every age had contributed to their advancement. His curious wax-work figures, together with his numerous and very ſkilful injections and preparations of various parts of the human body, attracted the attention of every ſpectator; and were no leſs an evidence of a fine taſte, judgment and accuracy, than the Lecture was of extenſive reading, and perfect knowledge of the ſubject on which he treated. During the exhibition the company gave the ſtricteſt attention, and ſatisfaction evidently impreſſed upon every countenance, teſtified a grateful ſenſe of the pleaſure they enjoyed. The whole was conducted with the greateſt politeneſs and decorum, and the company departed, expreſſing themſelves in the moſt terms of approbation.

Fig. 6 From the Pennsylvania Gazette. November 30, 1774.

The notice of the regular course of lectures (fig. 7) appears in the *Pennsylvania Journal and the Weekly Advertiser* for Novem-

ber 30, and December 7, 1774, and also in the issues of the *Pennsylvania Gazette* of the same dates.



At the ANATOMICAL MUSEUM in Videl's-Alley, Second-ſtreet, on Wedneſday the 7th of December, at ſix in the evening, Doctor CHOVET

WILL begin his COURSE of ANATOMICAL and PHYSIOLOGICAL LECTURES, in which the ſeveral parts of the human body will be demonſtrated with their mechaniſm and actions, together with the doctrine of life, health and the ſeveral effects, reſul[illegible] the actions of the parts, on his curious collection of Anatomical wax-work, and other natural preparations, to be continued the whole winter until the courſe is compleated.

As this courſe will not be attended with the diſagreeable ſight nor ſtench of recent diſeaſed or putrid carcaſſes, which often diſguſt, ſeven the ſtudents in phyſick) as well as the curious, otherwiſe inclined to this uſeful and moſt ſublime part of natural philoſophy, it is to be hoped this undertaking will meet with ſuitable encouragement.

TICKETS to be had for the whole courſe at Doctor Chovet's houſe in Second-ſtreet, Philadelphia.

Fig. 7 From the Pennsylvania Journal and Weekly Advertiser. November 30, 1774.

Norris, writing about the year 1845, says:

The building still stands upon the south side of the alley. It is a quaint looking old-fashioned two-storied brick house, with a steep pitched roof and dormer windows; it is now used as a carpenter shop. In this locality his lectures continued to be given, and his anatomical collection remained until 1777, when the latter was removed to his dwelling in Water Street, near the old ferry. Here he erected an amphitheatre in which his lectures were afterwards delivered, the first being given there in January, 1778

One of those who attended Chovet's first course of lectures has recorded the fact. Christopher Marshall, a retired druggist, makes this concise entry in his Diary under the date of January 27, 1775, "At Dr. Chovet's lecture." In the process of time these two men became friends. We shall meet them again before this account is finished.

During the years 1776 and 1777 the lectures given by Chovet appear to have been the only lectures on anatomy that were given in Philadelphia. Dr. William Shippen, Jr., the professor of

anatomy at the College, was at this time with the army and unable to give his course of lectures.

Chovet must have been, at this time, a man of some property. In London he lived in Leicester Square, noted in after years as the residence of John Hunter, and in Philadelphia he was able to live in what was, at that time, the chief place of residence of the best families of the business class, Water Street, and to build there in connection with his dwelling an anatomical amphitheatre. Soon after the peace of 1783, we find him located in Race Street, between Third and Fourth Streets. Water Street had in a great measure lost its prestige. Front Street and Second Street with the streets leading off from them had become the medical center. Dr. Rush lived on the east side of Front Street, above Walnut Street, in a "bank house without a foot of yard." Locality did not play as important a part in a physician's success then as now. Norris describes Chovet as being "a very popular physician, who came here from the West Indies," and his location on the outskirt of the chief medical center, in 1783, does not seem to have interfered with his practice. At this time he apparently had given up his anatomical lectures, for I have been unable to find any reference to them after his removal to Race Street.

We have seen that previous to Chovet's appointment as demonstrator of anatomy in The Barber-Surgeons Company he had prepared a considerable number of wax models, the list of which is given on the last page of his Syllabus (fig. 3) and from his preface we learn that he had still others in contemplation.

John Morgan said: "Chovet . . . . has indeed a good collection of wax preparations, of different parts of the human body, which he made in his younger days and brought hither from Europe."

On p. 157 I have quoted Chastellux's statement that the preparations brought to Philadelphia by Chovet were made in Barbadoes. Norris, in his sketch of Chovet in The Early History of Medicine in Philadelphia, says: "Dr. Chovet brought with him a complete and beautiful collection of anatomical preparations which he made in Barbadoes in 1744."

It would seem, therefore, that the statement of Morgan was not correct and that Chovet did not bring to Philadelphia those preparations made previous to 1732, but an entirely new collection made in Barbadoes. No wonder Chastellux describes Chovet as "invariably a man of application, and laborious."

John Adams was appointed one of the delegates from Massachusetts to meet with others from the other States in Congress, at Philadelphia, on the first day of September, 1774. He arrived in Philadelphia, August 29, 1774, and on the following day, Tuesday, August 30, "towards the evening, Mr. Thomas Smith . . . and Dr. Shippen and his brother, and Mr. Reed, went with us to the Hospital."

After visiting various parts of the Hospital, Mr. Adams says:

> Dr. Shippen then carried us into his chamber, where he showed us a series of anatomical paintings of exquisite art. Here was a great variety of views of the human body, whole and in parts. The Doctor entertained us with a clear, concise, and comprehensive lecture upon all parts of the human frame. This entertainment charmed me. He first showed us a set of paintings of bodies, entire and alive, then of others with the skin taken off, then with the first coat of muscles taken off, then with the second then with all—the bare bones. Then he showed us paintings of the insides of a man, seen before, all the muscles of the belly being taken off; the heart, lungs, stomach, etc.

I have quoted the above quite fully, for on Friday, October 14, Mr. Adams went to see Chovet and his collection and has made a most interesting comparison. Let us see what he has to say:

> Went in the morning to see Dr. Chovet and his skeletons and waxworks—most admirable, exquisite representations of the whole animal economy. Four complete skeletons; a leg with all the nerves, veins, and arteries injected with wax; two complete bodies in wax, full grown; waxen representations of all the muscles, tendons, etc. of the head, brain, heart, lungs, liver, stomach, etc. *This exhibition is more exquisite than that of Dr. Shippen at the hospital.*[2] The Doctor reads lectures for two

[2] Italics mine. W. S. M.

half joes a course, which takes up four months. These wax-works are all of the Doctor's own hands.

John Adams gives us only a partial list of what Chovet had in the way of anatomical equipment for instructional purposes. Not all of his equipment was in the form of wax models; he had a good supply of skeletons, better than some of the modern-day medical schools, besides a number of well made dissections and injections. It is fortunate for us that John Adams recorded so faithfully what he saw. It is quite evident that Chovet's collection was superior to the collection at the hospital. We have heard a great deal about Dr. Shippen and the hospital collection, and nothing at all about Dr. Chovet and his superior collection. It is difficult to understand the neglect.

Chovet had no place in the hospital, or in the young medical school which in after years grew into the medical department of the University of Pennsylvania, though I cannot but believe he was much the best anatomist in Philadelphia.

In order to understand what became of the collection which Chovet had, with so much industry, gathered together, we must go back to the year 1762, some years previous to the arrival of Chovet in Philadelphia.

At a meeting of the managers of the hospital held in the warden's room at the Court House, November 8, 1762, Dr. William Shippen, Jr., informed them that a gift from Dr. John Fothergill, of London, consisting of eighteen different views of anatomical structure, in crayon; three cases of anatomical models and one case containing a skeleton and fœtus had reached Philadelphia. The three cases contained three castings in gypsum. It is this collection that Dr. Shippen showed to John Adams.

George B. Wood in An Address on the Occasion of the Centennial Celebration of the Founding of the Pennsylvania Hospital says,

> These served as the basis of a Museum, which was afterwards greatly increased (April, 1793) by the purchase from the executors of Dr. Chovet, an eminent, but somewhat eccentric physician of Philadelphia, of his

collection of preparations and wax models, then deemed master-pieces of art in that department. The museum thus created was considered at one time among the greatest attractions of the Hospital, and even added somewhat to its receipts. But losing at last its value in this respect, and occupying space which was wanted for the more important purposes of the Institution, the Managers very courteously made an offer of it to the University of Pennsylvania, where it might be employed to greater advantage. The purchased cabinet of Dr. Chovet was made an absolute gift; but the collection presented by Dr. Fothergill, as the Managers did not conceive that they had the authority to alienate it, was merely placed with the University on deposit. The transfer was made in April, 1824, and the two collections at this time (1851) form a part of the Wistar Museum.

Probably Dr. Shippen was only too glad to have the use of the fine preparations made by Chovet; and the hospital, though Chovet did not have a place on its staff, considered itself fortunate in acquiring his collection.

In Morton's History of the Pennsylvania Hospital, a more complete account of the collection is given: "In 1793, the Managers acquired for the Museum a very remarkable collection of anatomical preparations, including dried, injected and painted specimens, together with a series of beautiful wax models by Dr. Abraham Chovet, by purchase from his heirs. The collection, especially the wax preparations, were regarded at that time as masterpieces of art."

A special caretaker of the museum was appointed and we have the record of the receipt of the collection.

PENNS. HOSPITAL, 25th 8 mo. 1806.

Received under my care and responsibility from the Managers of the Hospital all the articles of the Anatomical museum contained in the list thereof viz:

Imitations of the internal parts of the human body in wax by the late Dr. Chovet from No. 1 to No. 8 inclusive.

Dried preparations by the late Dr. Chovet and others from No. 1 to No. 93 inclusive.

Preparations of different parts of the human body in Spirit of Wine, by the late Dr. Chovet and others from No. 1 to No. 60 inclusive, and

Three Castings in Gypsum, and eighteen Paintings in crayons; presented by Dr. Fothergill of London.

SAML. C. HOPKINS.

From this list we learn that nearly the whole of the working museum consisted of preparations made by Chovet. A few were made by 'others' but no mention is made of them by name. Evidently Dr. Shippen was not as practical an anatomist as Chovet. If Dr. Shippen had possessed any of the spirit of his great teachers, John Hunter, William Hunter and William Hewson, it seems as though at this time his name would have been associated with some one of these preparations. It was not until the time of Wistar that any steps were taken toward the establishing of a permanent museum in connection with the department of anatomy at Pennsylvania. The present collection, housed in The Wistar Institute, is the direct result of the labor of Wistar and his successors.

We have seen that Chovet's collection first passed into the possession of the Pennsylvania Hospital and later was transferred by the hospital to the Wistar Museum. Thinking it might be of interest to photograph some of the preparations I opened correspondence with the present director of The Wistar Institute, only to meet with disappointment. Dr. Greenman made a most careful search and the result is embodied in the following letter:

February 25, 1909.

MY DEAR DOCTOR MILLER:

I had a curious hunt for the specimens made by Dr. Chovet. From the catalogue, Dr. Stotsenburg sent me the enclosed list which he says were entered before 1850 (1806. See above), and there seems to be no trace of any of these specimens in the University or The Wistar Institute. I presume they were among some specimens which were destroyed by fire some years ago, 1888, I believe. Regretting that I cannot furnish you more satisfactory data, I am,

Yours sincerely,

M. J. GREENMAN.

The question "What were the preparations mentioned and what became of them?" is now answered. I think my readers will agree with me that the answer is 'unsatisfactory.' It is a matter of great regret that a collection at one time the best in this country and one of the best in existence, for Chastellux says it "appears superior to that at Bologna," should have completely disappeared.

We have considered Chovet as an anatomist; we will now consider him in his individual character. Our compatriots of the time of the Revolution failed to understand him and his eccentricities. More than a century has passed since his decease and no one has been able to penetrate the mystery that surrounds his life. It may be that some future writer will be able to supply the much needed information.

When Chastellux visited Chovet in 1780, he found him even more interesting than his anatomical collection.

> On seeing him, one can with difficulty conceive how so much patience and perseverance could consist with his natural vivacity; for it seems as if the sun of the tropics had preserved in him all the heat of youth; he speaks with fire, expresses himself as well in French, as if he were still in our schools of surgery. In other respects, he is a perfect original: when the English were in Philadelphia he was a whig, and has become a tory since they left it; he is always fighting after Europe, without resolving to return, and declaiming constantly against the Americans, he still remains amongst them. His design in coming to the continent, was to recover his health, so as to enable him to cross the seas: this was about the commencement of the war; and, since that time, he imagines he is not at liberty to go, though nobody prevents him. He was to me a greater curiosity than his anatomical preparations, which appear superior to those of Bologna.

Chastellux gives here an example of Chovet's contradictions. A Whig while Philadelphia was occupied by the British forces, but a Tory before and after its occupation by the British: berating the Americans, he refuses to leave them. Chastellux, I think, understood Chovet better than his neighbors in Philadelphia.

I have spoken of the friendship that existed between Chovet and Christopher Marshall. This friendship was to be put to the test; and, if I read the account rightly, the better spirit was shown by Chovet, the Tory.

Our Revolutionary compatriots were, to put it mildly, radical. The story of Dr. Kearsley is known to every reader of the history of the Revolution. Chovet fearing a like treatment sought protection at the house of Christopher Marshall but was refused entrance. He hid in the hay in Mr. Marshall's stable and though the stable was entered twice by searching parties, escaped detection. Late that night he announced his escape by tapping on one of Mr. Marshall's windows. In the process of time Philadelphia was occupied by the British forces and Mr. Marshall's property was in danger. Marshall himself fled the city; but his good friend Chovet, the Tory, took into his own house some of Mr. Marshall's personal property and preserved it for him. Marshall himself is authority for this last statement. In his Diary we read under date of August 27, 1778: "Sent son's cart and horse to Dr. Chovet's and brought what books he had saved of mine at two trips to son's shop; left them up stairs there."

I think you will agree with me that the Tory had the better spirit of the two.

Although Chovet was an outspoken Tory, in time the people in Philadelphia came to regard him as harmless. Watson, in his Annals of Philadelphia and Pennsylvania, says: "The Doctor was what was termed a tory; was licensed to say and do what he pleased, at which no one took umbrage."

Chovet was thoroughly English in his sympathy, and he never let slip an opportunity to joke his Whig friends. Watson, in the above mentioned Annals, tells the following story, which illustrates the quickness of his wit.

> Having been sent for by the Spanish minister, Don Juan (I forget his name) who resided in old Mr. Chew's house, in Third, between Walnut and Spruce Streets, the weather being rather unpleasant, the ambassador ordered his carriage to the door to convey the doctor home—the doctor, full of fun and joke, directed the coachman to drive by the

Coffee-House, which, as he approached was perceived by the merchants, who immediately drew up in order, hats off, to pay their respects to the Don, as minister from a friendly power. The doctor kept himself close back in the carriage until directly opposite the Coffee-House; the gentlemen all bowing and scraping, when he pops out his head—"Good morning gentlemen, good morning; I hope you are all well; thank you, in the name of his majesty, King George," and drove off laughing heartily at having again joked with the Philadelphia whigs.

Norris tells the following story to illustrate his proclivity to use certain expletives in conversation:

The doctor happened to be overtaken at the house of a member of the Society of Friends by a heavy shower of rain, and as he insisted on pursuing his way during its continuance, the friend kindly offered to loan him his overcoat, adding the condition that he was not to use hard words while it was upon his back, to which the latter assented. On returning the coat he was asked, "Well, doctor, didst thou swear whilst thou hadst on my coat?" "No," replied he, "but there was a damnable disposition to lie."

The best character sketch of Chovet, as he appeared in his old age, is that given by Watson. I quote it in full.

One of the earliest, and one of the most vivid recollections in this city by the reminiscent, is of the person of old Dr. Chovet, living, at that time, directly opposite the (1842) 'White Swan,' in Race above Third Street. He it was who by his genius, professional skill and perseverance, finally perfected those wonderful (at that time) anatomical preparations in wax, which, since his death, have been in the possession of the Pennsylvania Hospital. These anatomical preparations, the very sight of which is calculated to fill the mind with solemn awe, while beholding not only the streets, but the lanes, alleys and inner chambers of the microcosm or little world of man, was beheld by the writer only some few years since, forcing back upon the memory the once aged appearance of the doctor, contrasted with the exertions made by him, and apparent to every one who beheld him, to appear active and sprightly in business, cleaving as it were to his 'last sand.' This aged gentleman and physician was almost daily to be seen pushing his way, in spite of his feebleness,

in a kind of hasty walk, or rather shuffle; his aged head, and straight white hair, bowed and hanging forward beyond the cape of his black old-fashioned coat, mounted by a small cocked hat, closely turned upon the crown upwards behind, but projectingly, and out of all proportions, cocked before and seemingly the impelling cause of his anxious forward movements; his aged lips closely compressed (sans teeth) together, were in continual motion as though he were munching something all the while, his golden-headed Indian cane, not used for support, but dangling by a knotted black silken string from his wrist; the ferrule of his cane, and the heals of his capacious shoes well lined in winter time with thick woolen cloth, might be heard jingling and scraping the pavement at every step; he seemed on the street always as one hastening as fast as his aged limbs would permit him, to some patient dangerously ill. without looking at any one passing him to the right or left; he was always spoken of as possessing much sarcastic wit; and also for using expletives in his common conversation, in the opinion of those who spoke on the subject, to be neither useful nor ornamental.

This picture of the old and faithful doctor is not a pleasant one. Evidently he no longer enjoyed the prosperity of former years. The fact that he always visited his patients on foot is not so surprising; it was the usual custom in those days. The especially well-to-do physician had his chaise, in these days he has his automobile. *Omnia mutantur, nos et mutamur in illis.*

The frontispiece is taken from an etching by Rosenthal, of the oil painting of Chovet by Pine, now in the possession of the College of Physicians of Philadelphia. It was made in his younger days and shows him wearing a cheerful and animated expression. Through the kindness of Dr. G. W. Norris, of Philadelphia, I have been able to reproduce a copy of the miniature portrait mentioned on p. 147. It was my intention to have a fresh impression made; but, to my regret, I received a reply to my letter of inquiry stating that "the medallion portrait in wax of Dr. Chovet has been damaged by a fall." In a later communication I was informed "the medallion will be repaired, but just when I do not know."

The medallion portrait was presented to the Pennsylvania Hospital in December, 1871, by Mrs. Mary Ann Marshall. It

was originally given to Mrs. Marshall's grandfather, in 1793, by Chovet's daughter, Susannah Maria Penelope Abington. On the back of this medallion appears the inscription "Abraham Chovet, born May 25, 1704; drawn May 25, 1784, by his servant Dr. Eckhout." It is earnestly hoped that this medallion can be restored.

As a practitioner of medicine and surgery Chovet was not without reputation. I quote again from Norris: "Dr. Coste, the chief medical officer of Rochambeau's army, in a tract which he published at Leiden, in 1784, speaks of Chovet as a man skilled in all thing pertaining to medicine, and especially in anatomy and surgery."

In the short sketch of Chovet in Morton's History of the Pennsylvania Hospital, it is said: "His character and the high quality of his professional acquirements entitled him to high rank among the medical profession, and with them to respectful remembrance."

Only one honor came to Chovet during his residence in Philadelphia, and that was well deserved. I find the following in Ruschenberger's sketch of Chovet:

> Of the twelve senior founders of the College of Physicians of Philadelphia Dr. Chovet is the one who was not born in or near Philadelphia. At the time of forming the Society his years exceeded four score. At such an advanced age men are not invited to engage in a new enterprise unless their qualifications are eminent in the estimation of their colleagues.

Strange to say no record was made in the minutes of the proceedings of the College, of the death of Chovet, although he was one of the charter members.

Chovet was probably married in England, for the tombstone of his daughter, Mrs. Abington, tells us that she was born October 30, 1736, and died April 3, 1813.

Chovet said "that physician is an impostor who did not live till he was eighty;" he died March 24, 1790, in the eighty-sixth year of his age. Chovet, his wife and his daughter are buried in Christ Church cemetery, Philadelphia.

Dr. Habraham Chovet Æ. 80
Drawn by his servant
Dr. Van Eckhout

Reproduced from Norris' Early History of Medicine in Philadelphia, by the permission of Dr. G. W. Norris.

In the notice of his death which appeared in the *Universal Asylum and Columbian Magazine* for March, 1790, he is referred to as "an eminent anatomist and extraordinary man;" the notice goes on to say: "This aged physician for about half a century attracted the attention of persons of all ranks and classes, in different parts of the world."

Shortly before he breathed his last he requested his family to give him a plain funeral, and by no means to have the bells, as was the custom at that time, rung for him: because he did not wish to have sick people disturbed by such an unnecessary noise. He often had had no consideration for people in health, but the sick always fared well at his hands.

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ON THE RELATIONS BETWEEN THE MESENCHYMAL SPACES AND THE DEVELOPMENT OF THE POSTERIOR LYMPH HEARTS OF TURTLES

FRANK A. STROMSTEN

From the Laboratories of Animal Biology, State University of Iowa

THREE FIGURES

In a recent paper read before the American Society of Zoölogists, Central Section, the writer called attention to the fact that, in the turtles, the mesenchymal spaces play a much more important part in the development of the lymphatic system than they seem to play in mammals. In a later paper before the Iowa Academy of Science, on the "Development of the Posterior Lymph Hearts of the Loggerhead Turtle," considerable stress was placed upon the importance of the intercellular lymph spaces in initiating the development of the lymph hearts. Since then a more careful study has been carried on with special reference to these spaces in embryos just before, at the time of, and immediately after the first appearance of the anlagen of the posterior lymph hearts. It is the purpose of this paper to consider merely a few of the results obtained by this study. A more detailed account is reserved for a later paper on the anatomy and development of the entire lymphatic system of the loggerhead turtle.

The embryonic material forming the basis for this work was collected by the writer at the Marine Laboratory of the Carnegie Institution at the Dry Tortugas, Florida. I wish here to express my deep obligations to Dr. Alfred G. Mayer, Director of the Tortugas Station, for valuable assistance in collecting the material; and to Professor Gilbert L. Houser for many helpful suggestions during the pursuance of this investigation.

A great deal of attention has been paid to the methods of preparing the materials for study during this research. It is extremely important for the correct interpretation of the significance of the mesenchymal spaces that the tissues of the embryo should be preserved in as nearly their natural condition as possible. A full account of the methods will be given in the later paper.

The posterior lymph hearts of turtles are a pair of elliptical, pulsating organs situated immediately below the carapace, just back of the upper ends of the iliac bones, one on each side of the body. They drain the lymph cavities and lymph channels of the posterior extremities and pelvic regions, and open into tributaries of the posterior renal advehent veins.

The only important work that has hitherto been done in the development of the sauropsidian lymph hearts, as far as is known to the writer, is that on the chick by Sala ('00). According to Sala's researches, the posterior lymph hearts are derived from the first five coccygeal veins of each side by a process of dilation and confluence. He finds that small spaces or fissures develop in direct connection with the lateral branches of these veins. These fissures appear to be merely the simple dilation and ramifications of the veins themselves. These spaces or fissures enlarge and fuse with each other, producing a "system of cavities, very irregular in form and dimensions, intercommunicating, and connected at the same time with the lateral branches to the first five coccygeal veins." The cavities subsequently fuse to form a single cavity for each lymph heart.[1]

The posterior lymph hearts of the turtles are closely related in their development to the formation of a pair of vessels, extending along the outer surface of the muscle plates of the post-iliac regions, and forming one of the main tributaries of the renal portal system of each side. This pair of veins we shall designate in this paper as the right and left caudal branches of the posterior renal advehent veins. They correspond to the venae ischiadicae of many authors. The right and left caudal branches of the renal advehent system

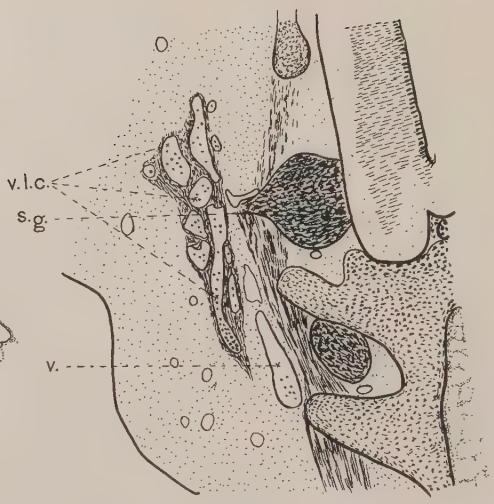
[1] Sala; "Sviluppo dei Cuori Linfatici e dei Dotti Toracici nell 'Embrione di Pollo," pages 269 and 270. See, also, Huntington; Anatomical Record, vol. 2, p. 34.

arise by the longitudinal anastomosis of the dorsolateral branches of the postcardinal veins, posterior to the opening of the iliac veins, and just outside of the muscle plates. They continue backward into the tail as the lateral coccygeal veins, and forward as the main branches of the advehent system of the Wolffian bodies. The development of the lymph hearts is directly related to that portion of these veins formed by the first two or three post-iliac branches of the postcardinal veins.

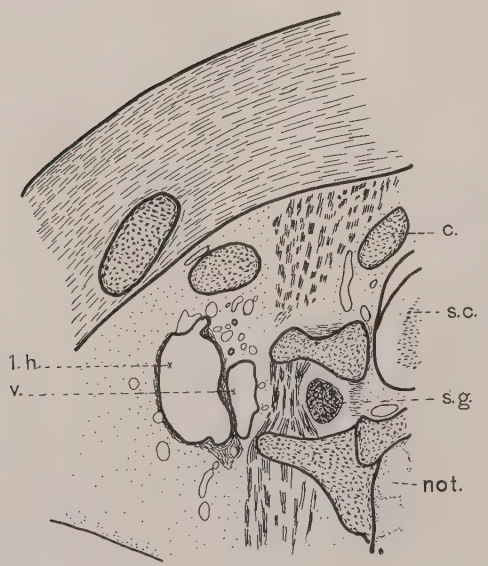
The development of the posterior lymph hearts is initiated in the loggerhead turtle by the vacuolation of the subcutaneous mesenchymal tissue of the post-iliac regions. As early as the middle of the second week of development, a noticeable change in the mesenchymal cells of this region is clearly seen. The mesenchyme becomes very loose and spongy. Toward the close of the second week, the mesenchymal spaces enlarge and fuse with each other. There is thus formed a network of intercommunicating spaces which invest and communicate with invading capillaries from the first two or three post-iliac branches of the postcardinals. Fig. 1 is a camera lucida drawing of a small portion of this area under the homogenous immersion lens. The spongy appearance is not sufficiently brought out in this drawing, yet it shows to some extent the nature of the vacuolation, and the relations of the spaces to the blood capillaries. By the middle of the third week of development, the dorsolateral branches of the postcardinal veins have fused at their distal ends to form the caudal branches of the renal advehent system. The formation of this pair of veins produces profound changes in the post-iliac spongy area. Great spaces or channels appear. These spaces seem to be enormously dilated capillaries which intercommunicate with each other, and connect with the accompanying veins at one or two points. They contain red blood cells, and are indistinguishable from the veins of that region, except by their position. They correspond to the veno-lymphatics of birds and mammals.

Hand in hand with the formation of the veno-lymphatic channels, there occurs a condensation of the mesenchyme in their immediate vicinity. The great accumulation of lymph in this

1



2



3

region has now found an outlet into the venous system through the veno-lymphatic channels. The mesenchymal spaces are then either absorbed by the veno-lymphatics, or their walls collapse so that the tissue becomes much more compact than it formerly was. Immediately surrounding the veno-lymphatics the condensation has gone so far as to form definite walls for these channels.

The veno-lymphatic anlagen of the lymph hearts increase rapidly in size, during the third and fourth weeks. A process of absorption of the septal walls between the several anlagen takes place during the later part of the fourth week. Beginning at the anterior end and proceeding posteriorly, the several spaces fuse with each other so that near the beginning of the fifth week, single cavities are formed for each lymph heart. In the meantime, muscle cells have wandered in from the adjacent muscle plates, completing the essential steps in the formation of the lymph hearts. Fig. 2 is a representation of the veno-lymphatics of a twenty-five day old embryo of the loggerhead turtle. The veno-lymphatic channels still contain red blood cells. They are readily distinguished from the accompaning vein by their denser walls. Fig. 3 is a section through the lymph heart of a loggerhead turtle embryo of thirty-two days development.

The results of this investigation show that the mesenchymal spaces have an important function to perform in initiating the development of the posterior lymph hearts. The importance of the intercellular spaces is probably more clearly brought out in turtles than in birds and mammals, because in the latter we are dealing with more or less rudimentary structures. A study of the development of the anterior lymph sacs of the turtle, itself, would indicate as much. This, however, will be considered at another time. In the highly specialized, or, in some cases, rudimentary lymphatic structures of birds and mammals, the earlier stages are passed through too rapidly, and are too slurred or masked to enable one to determine accurately the exact condition of affairs. Even in the present series of turtle embryos, which represent stages preserved at morning, noon, and night for every day of development from the time of laying until hatching, it will

be necessary during the present summer to fill in certain critical stages in order to determine positively whether the veno-lymphatics represent true modified capillaries or not. There are indications that in the development of both the lymph hearts and the lymph sacs of the loggerhead turtle, the mesenchymal spaces play an even more important part than has been assigned to them in this paper.

NOTE ON AN ANOMALY OF THE POSTCENTRAL SULCUS SIMULATING THE DOUBLE ROLANDIC OF GIACOMINI

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ONE FIGURE

In the course of an examination[1] of the brain of a hydrocephalic imbecile for the purpose of correllating the gyral map and histological stratigraphy with the normal, an anomalous or at least an unusual course of the right postcentral sulcus was met.

The Rolandic fissure follows a course of common type though it does not reach the mesial border of the hemisphere and the genu is represented by a very slight backward deflection.

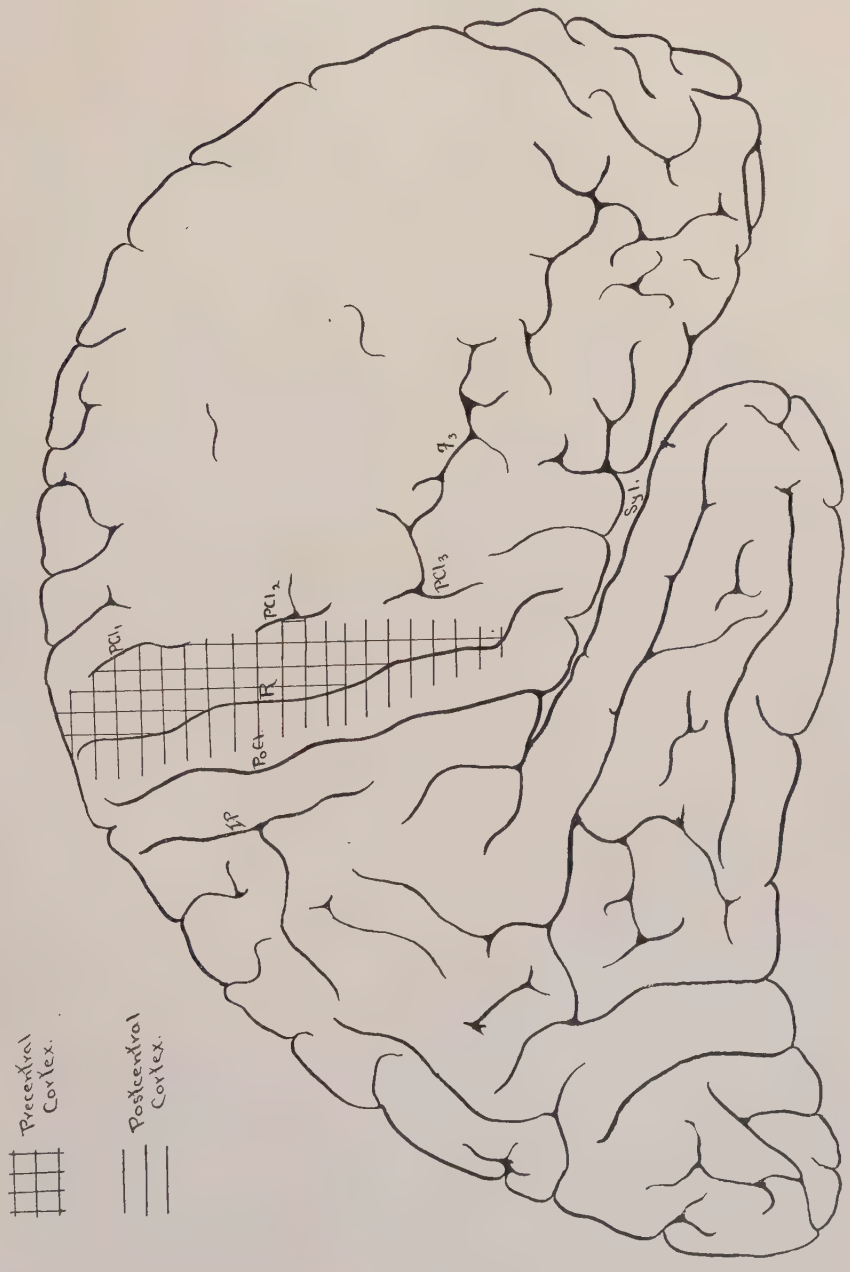
The postcentral begins in the Sylvian and runs parallel to the Rolandic at a very slightly varying distance of 12 mm. to within 5 mm. of the mesial border. The sulcus is very straight and uninterrupted and receives no branches giving the hemisphere the appearance, illustrated by Giacomini in his "Circonvoluzioni Cerebrali dell' Uomo" (second edition, 1884, p. 48).

Giacomini illustrates what he terms a reduplication of the fissure of Rolando and speaks of the two sulci as the anterior and posterior Rolandic sulci and calls the intervening gyrus the gyrus Rolandicus. The illustrations show a somewhat similar arrangement on both hemispheres and the author quotes Benedikt as in agreement with the view that the two fissures on the right are a reduplication, but as believing that the more anterior of the two on the left is an anomaly of the precentral sulcus. Zernoff on the other hand is quoted as believing the more posterior in each instance to be the postcentral sulcus.

[1] To be published later.

The stratigraphic examination of the cortex in the brain here reported leaves no doubt as to the true classification of the fissures in question. Cortex of the motor type is found investing the anterior wall and floor of the more anterior of the two fissures, while the uninterrupted long gyrus between the two fissures in question, *i.e.*, Giacomini's gyrus rolandicus—shows a structure on its anterior wall and surface which is unquestionably of postcentral type, grading off posteriorly into Campbell's intermediate postcentral thus identifying the posterior fissure as the postcentral.

Comparison of the brain map of the present case with Giacomini's two illustrations leads to the opinion that Zernoff's belief was the correct one and that the anomalous sulcus on both sides in that case was also the postcentral.


PCl1
PCl2
PCl3
IR
PoCt
ip
Precentral Cortex.
Postcentral Cortex.

ON THE DEVELOPMENT OF THE TWO FIRST BLASTOMERES OF THE FROG'S EGG

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In vol. 10 of The American Journal of Anatomy, MacClendon has recently contributed observations on "The development of isolated blastomeres of the frog's egg." Operating on the egg of Chorophilus triseriatus at the two-cell stage, the author has succeeded not only in injuring one of the blastomeres, but in removing completely one of them, without the death of the other. A great mortality was met with. In some cases, however, MacClendon observed that whole embryos developed from the remaining blastomere. The latter result could be foreseen; the experiments of O. Schultze and Morgan showing beyond a doubt that one blastomere of the frog's egg at the two-cell stage is able to give rise to whole embryos. I have myself corroborated this observation at various times, but would have deemed its publication merely a confirmation of well-known facts.

MacClendon seems to have at his disposal a material and a method which could enable him to analyse the facts more closely. This author states that in his experiments the position of the grey crescent as marking the future dorso-anterior region was not recorded; neither does he give the exact percentage of the whole embryos. In omitting these facts, especially the former, it would seem to me, that he lost an opportunity of making interesting observations, namely, of giving a new and important proof of the decisive part played by the bilateral symmetry and the grey crescent in the developing powers of the two first blastomeres. The fact that he did not obtain half-embryos, but a few whole embryos among a large number of dead eggs, presenting more or less striking defects, seems to prove that the whole embryos, de-

veloped from eggs in which the first cleavage plane coincided with the plane of bilateral symmetry, and, had he verified the fact before removing one of the blastomeres, his experiments would have been conclusive and the problem solved. In the same manner, had he carefully noticed the degree of development of the remaining blastomere, after the removal of the other, in the cases of anachronism of segmentation (Roux) as well as in the cases where the plane of symmetry makes an angle of 45° towards the right or towards the left with the first cleavage plane, he would have derived some data from the so-called unsuccessful experiments and perhaps he might have been able to analyse very closely the germinal localisations in the frog's egg.

In my "Recherches expérimentales sur l'oeuf de Rana fusca." (Arch. de Biologie T. XXI, 1904) to which MacClendon does not refer, I made such an analysis by simply pricking one blastomere with a hot needle. It would have been very interesting to see the confirmation of my results by the method of MacClendon, for, if the conclusions of this author are partially identical with certain of my own, it must be seen they are not wholly substantiated by the facts which he observed. He states (p. 430): "It appears then that the egg at the time of the first cleavage is differentiated in the direction of the primary axis, and furthermore in the direction of a plane passing through this axis and bisecting the grey crescent, so that the egg may be divided in this plane into two totipotent halves. The halves of the egg divided in any other plane may or may not be totipotent. The formation of a half embryo instead of a whole embryo from one blastomere of the two-cell stage is due to the presence and mechanical interference of the other blastomere." These conclusions, it would seem to me, are not warranted as deductions from his experiments, he having neglected to use the means of control which were at his disposal, in not examining the relations borne between the grey crescent and the plane of first cleavage.

This means of control has allowed me to demonstrate that the portion of the embryo developed from one blastomere is strictly dependent on the relation existing between the plane of first cleavage and the middle of the grey crescent. The production of hemi-

embryos is only possible in cases of coincidence of these two planes and as early as 1904, I expressed the idea, which Driesch and others have fully corroborated, that it is only under the above mentioned conditions that double embryos can be obtained by the Schultze's method, as well as whole embryos developed from one blastomere by the method of Morgan.

MacClendon expresses the same thought when he states that a plane passing through the axis of the egg and bisecting the grey crescent divides the egg into two totipotent halves. It is to be regretted, that being in possession of a new, and as far as one can judge, an exact method, the author did not attempt to substantiate this fact by experimental proof.

The second sentence of the above quotation, it would seem to me is no better warranted by observed facts. In fact, as a result of my own experiments, which are in no wise invalidated by those of MacClendon, it is shown that the halves of an egg which divides in other planes may not be totipotent. There is no evidence which would allow MacClendon to say that they may be totipotent in some cases.

On the other hand MacClendon has by his method, given the proof, that the formation of a half embryo from one blastomere of the two-cell stage of the Roux' experiments is really due to the presence and mechanical interference of the injured blastomere.

BOOK REVIEW

Normentafeln zur Entwicklungsgeschichte der Wirbeltiere. Herausgegeben von Prof. Dr. F. Keibel. Elftes Heft.

Normal Plates of the Development of Necturus maculosus. By Albert C. Eycleshymer and James W. Wilson. Jena, Gustav Fischer. 1910. 50 pp., 3 plates.

When the publication of the series of normal tables for the purpose of standardizing the stages of development in the vertebrates was undertaken by Professor Keibel, Professor C. O. Whitman was drawn in to prepare the normal plates of the development of Necturus maculosus. When he was director of the Allis Lake Laboratory at Milwaukee in the years 1886–1889, Professor Whitman had collected complete series of the eggs of Necturus and had made many observations on the development; characteristically, he did not publish his incomplete observations, but held the material in reserve expecting to complete the study later. In his lectures he often referred to his observations on this form. Professor Keibel's invitation induced Professor Whitman to begin the preparation of the normal tables and plates, but later he resigned the work to Professor Eycleshymer and furnished him with material and information "without which it would have been impossible to complete the work."

The completed work now before us includes three beautifully executed lithographic plates of surface views of stages from the beginning of cleavage up to a larva 126 days after hatching, all drawn from living material. For the preparation of the tables, 49 in number, more than 250 series of sections were available, and for each of the stages designated series cut in three different planes were used. Only a professional embryologist can properly appreciate the immense amount of work that has gone into the preparation of this highly concentrated publication. The very complete bibliography includes all papers on the embryology and most on the anatomy, histology, systematics, etc., of the Perennibranchiata and Derotremata. Altogether, this number measures well up to the best of the other numbers, and American embryologists may well feel satisfied that they are so ably represented in this standard series.

F. R. L.

A METHOD FOR ISOLATING THE RENAL TUBULES OF MAMMALIA

G. CARL HUBER

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ONE PLATE

Two methods are available for ascertaining the size, shape, sequence and relations of the several parts of a renal tubule of mammalia, namely, reconstruction by the wax-plate method and maceration of kidney substance to an extent permitting isolation of tubules or tubule segments. Of these two methods that of reconstruction is the more satisfactory, within the limits of its applicability, since it permits of the reproduction of the several parts of a tubule in their normal relation and in permanent form. However, the complexity of the renal tubules, especially of adult mammals is such, that it is necessary to have for purposes of wax-plate reconstruction, first, an unbroken and relatively long series of sections, extending through cortex and medulla, and not to exceed 5 micra in thickness, and second, to use a magnification of about 400 diameters. The limits of applicability of the wax-plate method, therefore, is reached about with renal tubules taken from the kidneys of newly born or relatively young stages of the smaller mammals; the renal tubules of newly born rabbits and cats, thus reconstructed resulting in models reaching a length of between four and five feet. The size of the model which would result from reconstruction of a renal tubule of an adult mammal, but more especially the difficulty of tracing through an unbroken series of 150 to 250 sections the different parts of such a tubule, would relegate this method, under such conditions, to the position of one of the most difficult of technical procedures. The method of maceration is the older and has been very widely used. The rapidity and ease of its application, and the fact that large numbers of tubules or tubule segments are readily placed at the disposal of the observer, commend it. However, the methods of maceration as now very generally used are not without limitations, so that while the results of nearly all investigations dealing with form and relations of the several parts of the mammalian renal tubule are based on observations made with the aid of maceration methods, it has not been possible until very recently to even approach the isolation of a complete renal tubule in an adult mammal, all conceptions of their form and relations being

based on observations on shorter or longer tubule segments, a fact which readily accounts for the diversity of opinions as to many details in regard to form and structure current in literature. As macerating media, hydrochloric and nitric acid have been extensively used, especially the former. With arsenious acid, as recommended by Golgi, I have had only in different results. It is not my purpose, nor is it necessary to review the various methods and macerating media which have been used for the purpose of isolating the renal tubules; further than to call attention to the methods used by Peter[1] and Zarnik,[2] whose results deserve special consideration. Peter in a recent and most excellent contribution on the structure of the mammalian kidney, in which he gives an account of extended observations made largely on macerated material, made use of the hydrochloric acid method in the following way: Fresh and relatively large pieces of kidney substances were placed in concentrated hydrochloric acid solution. Hydrocloric acid of sp. gr. 1.124, that is, 24% H Cl was used either concentrated or 75 parts of the acid with 25 parts of distilled water. In this the pieces remained for from several hours to two days, the time varying with the size of the piece and other factors. When the desired degree of maceration was reached the pieces were rinsed several times in distilled water and then kept in the same. Pieces are now and then ready for teasing as soon as placed in the distilled water or not until after a stay in the water varying for from several to 48 hours. By means of this method it would seem that Peter obtained very complete maceration admitting of the isolation of relatively long tubule segments, as is attested by his excellent figures, among them a figure of a short, though practically complete renal tubule from the kidney of an adult mouse (fig. 1, plate 1, of his article) 5 mm. in length, which was, however, so unfortunately mounted that while it admits of the determination of the sequence of the several parts of a renal tubule there is presented no idea of their relation. Peter's diagrams and his statements concerning the length of the renal tubules of man and the other mammals investigated, excellent and accurate as they are, must be regarded as deductions drawn from an observation of relatively long tubular segments, and are not based on actual observation of complete renal tubules. Zarnik investigated the kidney structure of echidna and reptilia. The method used by him is essentially that of Peter, slightly modified as follows: Pieces of kidney, or the entire kidney if small, were placed in concentrated hydrochloric acid (strength not given) for one hour; transferred to distilled water for one hour; again placed in the acid for one hour and then placed in distilled water and kept in the same. To prevent the formation of fungus, the pieces were placed, after a stay of 12 hours in the water, in a solution consisting of 1 per cent formalin and 2 per cent chloral hydrate in dis-

[1]Peter, K-Untersuchungen über Bau und Entwickelung der Niere. Fischer, Jena, 1909.

[2]Zarnik, B-Vergleichende Studien über den Bau der Niere von Echidna und der Reptilienniere. Jenaisch. Zeitsch. f. Naturwissenschaft, Bd. 46, 1910.

tilled water, in which solution they may be kept for months. I shall refer here only to that portion of his contribution dealing with the structures of the kidney of echidna aculeata. The somewhat accidental selection of this form must be regarded as fortunate since the kidney of echidna appears peculiarly favorable for purpose of maceration, presenting as it does, stuctural peculiarities characteristic of the foetal kidney of the higher mammals, so that after maceration for a comparatively short time Zarnik was able to isolate many entire renal tubules although he regrets his inability to mount them in permanent form. The tubules described and figures present in the main the parts described for a mammalian renal tubule. No exact measurements are given for the complete tubules figured. The lengths given, admittedly not exact for the longest tubules, vary from 10 mm. to 30 mm., including if I interpret him correctly, the collecting ducts. The short renal tubules of the mouse figured by Peter and the several examples of the relatively simple renal tubules of echidna figured by Zarnik, constitute, so far as I have been able to ascertain the most successful attempts at the isolation of the complete renal tubules of adult mammalia. I should question the possibility of a more thorough maceration of kidney substance and a more complete isolation of renal tubules by the methods of Peter and Zarnik than was obtained at their hands.

It seemed desirable, therefore, to attempt an extension of the methods of maceration in their application to kidney tissue, more particularly to devise some means of obtaining a more uniform maceration throughout the whole mass, a method by means of which cortex and medulla might be more equally macerated as regards to time. The question of isolating complete renal tubules of adult mammals, appeared to me to depend on the possibility of obtaining complete and uniform maceration of the kidney substance without softening the tubules to an extent making manipulation impossible. This has in a great measure been obtained by injecting concentrated hydrochloric acid solutions into the blood vessels under moderately high pressure. It is the purpose of this note to describe the method devised, the results attainable being portrayed by means of several figures which represent camera lucida drawings of types of tubules isolated and permanently mounted. The method has been tested on the renal tissue of rabbits, cats, dogs, guinea pigs, and rats. From all of which it has been possible to isolate complete renal tubules if one may regard a tubule extending from the renal corpuscle to its junction with the collecting duct as an entire tubule, namely, that portion of a renal tubule which develops from a renal vesicle. Both Peter and Zarnik in their descriptions and in the measurements given have regarded the collecting tubules or ducts as constituting a part of the renal tubules. It would seem, however, more desirable to follow development and distinguish between the renal tubules proper and the collecting ducts. The method, for want of material has not been sufficiently tested on human renal tissue to enable me to consider at the present time the possibility of isolating entire human renal tubules. This is under contemplation.

Method: For purpose of maceration, I have used almost wholly solutions of hydrochloric acid made by mixing 75 parts of H Cl, sp. gr. 1.21, with 25 parts of distilled water. This makes a solution somewhat stronger than that used by Peter. The few trials with nitric acid have not been satisfactory. Only fresh tissue has been used. After anaesthesia, not carried to cessation of heart beat, the large vessels of the neck are cut and the animal suspended head downward to admit of free bleeding. The abdomen is then opened and a large cannula inserted in the aota, slightly above the origin of the renal arteries and the cannula filled with normal salt solution or distilled water. A pressure of from 10 lbs. to 15 lbs. as registered by the pressure gauge, was employed to inject the acid solution by means of an apparatus previously described (G. Carl Huber, The Arteriolae Rectae of the Mammalian Kidney, Amer. Jour. Anat., vol. 6, '06-'07, page 393). It is important to cause the acid to flow into the tissue as rapidly as possible and under relatively high pressure. Successful injections of the cortex are readily made. It is, however, quite difficult to obtain complete injection of the medulla, more particularly of the renal pyramid. The extent of the injection can usually be readily seen on a cut surface, the injected portions presenting a bleached appearance, the uninjected a more normal pink color. The kidney is allowed to remain in place for from 10 minutes to 15 minutes after the injection is completed, when it is removed, denuded of its capsule and cut in several pieces, the number depending on the size of the organ. In the rabbit and the cat it has been usual to cut the kidney twice crosswise, thus obtaining a central segment, including the renal pyramid and having a thickness of about 1 cm. at the cortical border. Obviously, this portion includes the straightest and longest tubules. The two end pieces are cut through the middle in the sagittal plane of the kidney. The pieces thus obtained are placed in a hydrochloric acid solution of the same strength as that used for the injection, using a relatively large quantity, about 150 cm. for one kidney of a rabbit. The pieces, which sink gradually, remain in the solution for from three to four hours. An exact statement concerning the time required cannot be made, the maceration being no doubt influenced by factors not wholly under control. So far as I have been able to determine, successful macerations are more dependent on a thorough injection of the hydrochloric acid than on the length of time which this solution is allowed to act after the injected tissue is placed in the same. The removal of the pieces from the acid is best accomplished by carefully pouring off the greater part of the acid, leaving only a sufficient quantity to allow the pieces to float. The dish is then filled with distilled water. This procedure is followed several times, or until practically all of the acid has been removed. After a stay in the distilled water of from 15 minutes to 20 minutes, during which time the pieces lose their transparency and become quite firm, they are transferred by means of a section lifter to fresh distilled water in which they remain several hours, a longer stay is, however, not injurious. From the distilled water the pieces are transferred to an alum hematoxylin solution—Mayer's hemalaun—but, before doing so it has

been found advantageous to tease carefully the larger pieces, so as to obtain small pyramidal segments of renal tissues, extending through all of the layers and having a diameter of about 3 mm. at the cortical border. These smaller pieces remain in the hematoxylin solution for from 24 hours to 48 hours; they, however, may remain in this stain for weeks without injury. Staining the smaller pieces, before final teasing, as here suggested is to be recommended and for several reasons: The staining solution appears to neutralize the acid remaining in the tissue; the course of the tubules is much more easily followed in stained than in unstained tissue during teasing and since the delicacy of the isolated tubule is such that their staining after isolation is practically excluded, the desirability of having stained preparations when finally mounted in glycerine is evident. Stained tubules are readily followed under low magnification, and admit of study under higher powers, by use of which the size and arrangement of the nuclei and to some extent their structures may be acertained. For a final teasing thoroughly cleaned Syracuse watch-crystals are used. These are nearly filled with distilled water to which a trace of ammonium hydrate is added—10 to 15 drops of a 0.5 per cent solution of ammonium hydrate in distilled water to each watch-crystal. The ammonia present develops the stain and softens slightly the tissue, so that the tubules become quite pliable. The hematoxylin solution causes the tissues to become quite brittle, this the trace of ammonia rectifies without effecting the tensile strength of the tubules. The teasing is carried on under the stereoscopic binocular and with very fine needles. Under favorable conditions one may readily isolate relatively long tubule segments and now and then an entire tubule. In the course of this study somewhat over 100 tubules extending from the renal corpuscle to the collecting duct have been isolated. It is, however, extremely difficult to mount such tubules in permanent form. Various methods have been tried without obtaining uniformly satisfactory results. With the following procedure it has been impossible to mount certain of the tubules isolated. A tubule which has been completely isolated, and preferably one in which the distal convoluted portion is not completely separated from the renal corpuscle or the coil complex of the proximal convoluted portion, is slowly drawn into a pipette with opening nearly as large as the lumen, the operation being controlled under the binocular, and is transferred to a small dish containing distilled water, and placed under the binocular. A thoroughly cleaned coverglass, 25 mm., by 20 mm. held at one end with coverglass forceps is inserted at an angle until almost completely submerged. The tubule is then worked onto the cover glass to the region where surface of water and cover glass meet. Then on slowly withdrawing the cover glass, it is now and then possible to cause the coil complex of the tubule to adhere to it. If this is accomplished, the further withdrawal of the cover, which needs to be done very gradually and evenly, will cause the medullary loop to arrange itself fairly regularly on the cover glass. After successful transfer of the tubule to the cover glass, this is placed for a few moments at an angle of about 45° to allow the adherent fluid to drain, the larger drops which collect at the

bottom are then removed with filter paper. Before the mounting can be completed it is necessary to allow of sufficient evaporation to cause the tubule to adhere to the cover glass, when it may be lowered, beginning with the edge nearest the coil complex, on a large drop of glycerine drawn out to the length of the cover glass. The glycerine is allowed to spread out very slowly. The preparation may then be sealed with asphalt. Of the tubules isolated only a few have been successfully mounted.

On the accompanying plate there are presented three types of renal tubules isolated from the kidneys of adult rabbits. The tubules here figured are permanently mounted in glycerine. The figures shown represent camera lucida drawings made at a magnification of 100 diameters, reduced five times in the reproduction. Tubule *A*, (fig. 1) which was isolated with a portion of the collecting duct, represents a tubule the renal corpuscle and coil complex of which were situated at the extreme periphery of the cortex. In tubule *B*, (fig. 2) the renal corpuscle and proximal coil complex were situated in the deeper portion of the outer half of the cortex. In tubule *C*, (fig. 3) the renal corpuscle and proximal coil complex were situated in the deepest portion of the cortex just above the medulla. Tubules *A* and *B*, I was able to transfer to the cover glass and mount in the form in which they were isolated by teasing. Tubule *C*, was successfully transferred to the cover glass after which it was found that a short segment of the distal, the thicker arm of the medullary loop adhered to the surface of the layer of water which had collected on the cover. In an endeavor to depress this portion of the tubule by means of a needle, the tubular segment in question adhered to the needle and was accidently separated. The region is indicated by the dotted lines. The tubules figured are not from the same kidney nor even from the same animal. The figures are placed on the plate with reference to the medullary zones and stripes described by Peter. This author has shown, and I cannot but regard this as a very distinct contribution on his part, that the substantia medullaris may be divided into an inner and outer zone and the outer zone further into an inner and outer stripe, each zone and stripe containing definite segments of the renal tubules; zones and stripes may often be observed in fresh material and even in fixed tissues. The boundary line between the inner and outer zones occurs in the region of the transition of the thin and transparent epithelium of the medullary loops to that of the dark thicker epithelium of the distal arms of the loops. The boundary between the inner and outer stripes of the outer zone is to be found in the region of transition of the thick medullary segments of the proximal arms to the thin segments of the medullary loops. The dotted line a-a, indicates approximately the boundary line between inner and outer stripes of the outer zone, with reference to which the tubules were given their relative position. The dotted line b-b, indicates approximately the boundary line between inner and outer zones. In obtaining the measurements here given I have made use of the method employed by me in ascertaining the length of renal tubules isolated by reconstruc-

tion, namely, of measuring the length of the tubule as found in the model and dividing the resultant figure by the magnification. This method is perhaps somewhat less accurate when applied to a figure, since in a figure it is difficult to represent exactly the length of loops which pass upward or downward in the line of vision. The measurements given are, therefore, rather too short, since such loops are as a rule somewhat fore-shortened. Peter, who has used the same method in ascertaining the length of the tubular segments isolated by him, has also called attention to this source of error. In the accompanying table of measurements taken, attention was given to the relative lengths of the tubular segments showing characteristic and specifically differentiated epithelium. The expression "to the level of the renal corpuscle" found in several of the column headings, has reference to the figures, and not to the actual relations maintained by the different parts of the respective tubules before teasing. In the first column "proximal convoluted portion from renal corpuscle to level of renal corpuscle" is to be interpreted as representing the length of the proximal convoluted portion of the respective tubules, begining in each with renal corpuscle following it through its several windings until the tubule returns to about the level of the renal corpuscle as seen in the several figures. The measurements given are approximate only to the extent of the very slight variation of the position of the several parts of each tubule as given in the figures from that which they obtained in the tubules before teasing and mounting. The lengths of the several parts of the renal tubules figured are as follows:

	PROXIMAL CONVOLUTED PORTION FROM RENAL CORPUSCLE TO LEVEL OF RENAL CORPUSCLE	MEDULLARY SEGMENT FROM LEVEL OF RENAL CORPUSCLE TO THIN SEGMENT OF LOOP	TOTAL LENGTH OF PROXIMAL CONVOLUTED PORTION AND MEDULLARY SEGMENT	THIN SEGMENT OF THE MEDULLARY LOOP	THICK OR DISTAL SEGMENT OF THE MEDULLARY LOOP TO LEVEL OF THE RENAL CORPUSCLE	DISTAL CONVOLUTED PORTION TO COLLECTING DUCT BEGINNING WITH LEVEL OF RENAL CORPUSCLE	TOTAL LENGTH OF TUBULE FROM RENAL CORPUSCLE TO THE COLLECTING DUCT
	mm.	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*
Tubule A, fig. 1	6.8	4.5	11.3	1.4	6.0	1.8	20.5
Tubule B, fig. 2	5.6	3.8	9.4	6.7	6.0	0.9*	23.0
Tubule C, fig. 3	7.7	2.5	10.2	15.0	2.6	1.0*	28.8

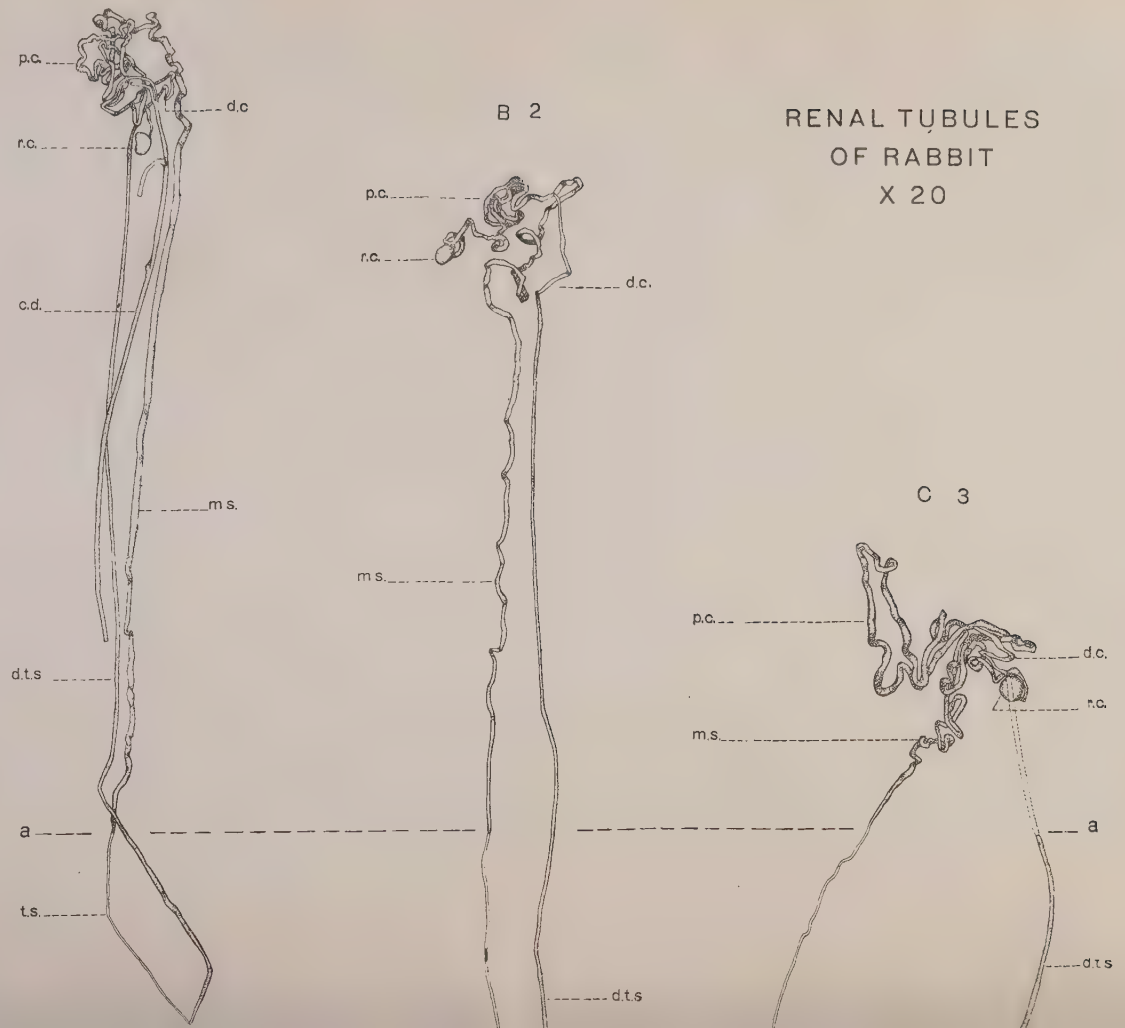
*Not traced quite to the collecting duct as may be seen from figures.

It is the primary purpose of this note to call attention to a method for isolating the complete renal tubules of adult mammals and to merely indicate by way of several figures of type-tubules the results which

may be obtained. A fuller discussion of the mammalian renal tubule is, therefore, withheld for the present. It may be stated, however, that tubules in which the renal corpuscle and proximal coil complex occupy essentially the same relative position in the cortex as those here figured present essentially the same general characteristics as the ones selected for consideration. Those selected represent type-tubules, *A* and *C*, extremes with *B*, holding an intermediate position. A larger series of tubules selected with reference to position of the renal corpuscle and proximal coil complex of the respective tubules at various levels of the cortex would give a series of figures which would show a gradual transition from a tubule of the type of tubule *A*, to one of the type of tubule *C*. These statements pertain not only to the tubules of the kidney of the rabbit but are equally pertinent to the renal tubules of other mammalian forms studied, with the understanding that the special characteristics of form and structure of renal tubule of the mammal under discussion be considered.

Attention may be drawn to the difference in the relative length of the tubule segments lined with epithelia presenting characteristics, structural peculiarities. I have previously drawn attention to the fact that at least four types of epithelium are to be found in the renal tubules of mammals. These are: (*a*) the pavement glomerular epithelium; (*b*) the characteristic renal epithelium of the proximal convoluted portion with its medullary segment; (*c*) the clear, pavement epithelium of the medullary loop; (*d*) the thicker, darker epithelium of the distal, the ascending arm of the medullary loop and the distal convoluted portion to near the collecting duct, the later regions presenting perhaps more than one type of epithelium. The measurements above given go to show that the length of those portions of the renal tubules lined by the specific renal epithelium of the cortex, namely, the proximal convoluted portions with their medullary segments, represent tubular segments which do not vary appreciably in length in the tubules of the various types, that, however, the thin tubular segments lined by the clear transparent epithelium of the pavement type vary in length within wide limits in renal tubules of different types. If one may assume a specific excretion for the special renal epithelium lining the proximal convoluted portions and their medullary segments, it is evident that this specific excretion would be essentially of the same extent for all of the renal tubules, irrespective of type. If on the other hand one may assume an absorbtion of water and perhaps certain salts in the segments lined by the clear, pavement epithelium the extent of this absorption must differ widely in tubules presenting short, intermediate and long tubular segments having this structure, and that, therefore, urine of different degrees of concentration must as a consequence enter the collecting tubules.

An outline of the method as here given was presented at the 1910, October, meeting of the Research Club of the University of Michigan, with a demonstration of certain of the tubules figured. A fuller account, accompanied by demonstrations, was presented at the Ithaca meeting, December, 1910, of the American Association of Anatomists.


B 2
RENAL TUBULES
OF RABBIT
X 20
C 3
p.c.
d.c
r.c.
c.d.
m.s.
d.t.s
a
t.s.
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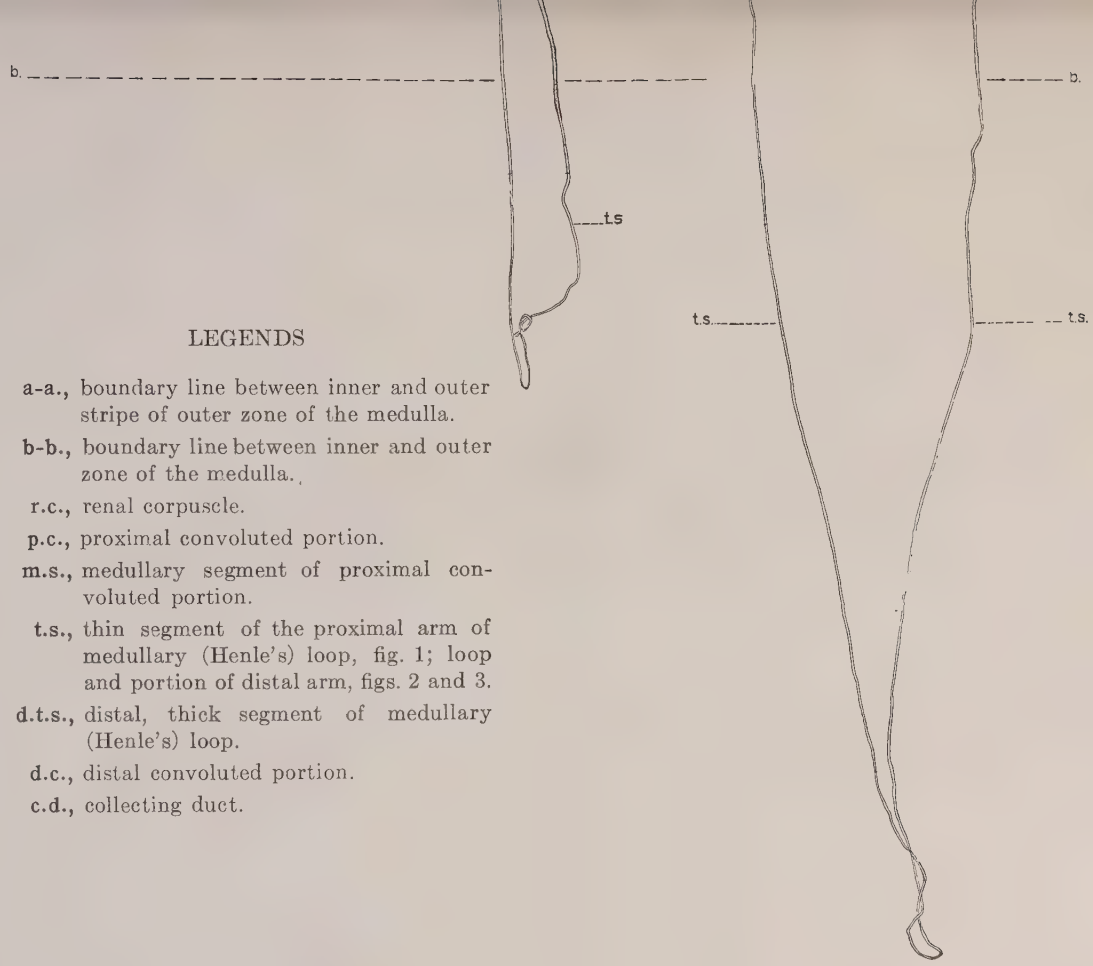

LEGENDS

a-a., boundary line between inner and outer stripe of outer zone of the medulla.

b-b., boundary line between inner and outer zone of the medulla.

r.c., renal corpuscle.

p.c., proximal convoluted portion.

m.s., medullary segment of proximal convoluted portion.

t.s., thin segment of the proximal arm of medullary (Henle's) loop, fig. 1; loop and portion of distal arm, figs. 2 and 3.

d.t.s., distal, thick segment of medullary (Henle's) loop.

d.c., distal convoluted portion.

c.d., collecting duct.

BOOK REVIEW

GEHIRN UND RÜCKENMARK. LEITFADEN FÜR DAS STUDIUM DER MORPHOLOGIE UND DES FASERVERLAUFS. Von Dr. Med. Emil Villiger. Zweite Auflage. Leipzig. Verlag von W. Engelmann. 1910. 278 pages and 224 figures. Price $4.00.

The second edition of Villiger's textbook on the nervous system will be welcomed by those who are giving courses based on the idea of fibre tracts. The majority of the best books on the nervous system have grown, as it were, into reference books and become too complicated and too detailed for class use. This should give a favorable reception to a book like Villiger's, which in my judgment is well adapted to class work. In fact I regard it as the best text available to give a class a foundation for understanding such knowledge as we have of the complicated subject of the nervous system. In the course of outlining its subject matter I shall hope to make clear why I regard the book as so well adapted to teaching. It will also no doubt prove of value to teachers and to practitioners who desire to get an easily grasped outline of the fundamental facts of the nervous system as accepted today.

The description of the gross anatomy of the brain, which takes about seventy pages, has many good features. First there is a brief general orientation of the brain as a whole, then of the lobes of the cerebrum and the convolutions. The brain is then described in detail with reference to function. For example, the entire olfactory area, namely the bulb and tract, the olfactory gyri, the gyrus fornicatus and the hippocampus are all grouped together, with excellent figures of foetal brains in which the surface markings are obvious, together with a number of good new figures of special details for the adult.

The thalamus is illustrated in its relations to the third and lateral ventricles. In a series of sections of the gross brain and by a simple and clear description the nuclei of the thalamus are made easy to place. Instead of a long list the three main ones, the anterior, medial and lateral, are first made clear, while the others are treated as accessory.

The brain stem is treated in a way which particularly interests me, because it correlates a considerable variety of surface views with microscopic sections. This is a point which I have long been interested in, for I think that the central nervous system offers almost the best material in anatomy for the correlation of the gross with the microscopic. The colored views of the lobes of the cerebellum give a good background for the study of localization. The meninges and cord are given a brief description, which ends the first part of the book.

The second part of the book deals in general with the fibre tracts. It begins with an account of the various methods on which our knowledge is based, a most important point commonly omitted in text books. The histogenesis of the cells follows, together with a good account of the newer methods of studying neurones and supporting cells. Then comes the general microscopic structure of the cortex, with a few details of special regions, together with a brief historical and general account of localization in the cortex. The speech centers, motor and sensory as usually given are clearly shown in a diagram but not too definitely outlined in the text.

There follow a great variety of clear, simple diagrams of tracts. The first one is for general orientation and is remarkably clear in showing the main sensory tract to the cerebellum and to the cortex, together with the rubro-spinal tract, the pyramical tract and the simple reflex paths of the cord. With this as a ground plan, the tracts are taken up in detail in the same order as the gross anatomy, namely those of the telencephalon, diencephalon, down to the tracts of the cord.

Then the cranial nerves are given with clear line diagrams which give the neurones from the peripheral sense organ to the cortex. This arrangement which gives the long tracts as the framework and the details of the cranial nerves later is the one I like best in class work. The second part ends with a general summary of tracts, sensory and motor, reflex and association.

The third part is an atlas of transverse sections extending from the anterior end of the caudate nucleus through the decussation of the pyramid at the lower end of the medulla. It is as far as I know the best series accessible to students and will be much used.

I am anticipating the use of Villiger's book with a class because it is based on a number of points which we have been using for a number of years in teaching the nervous system. I particularly like the introduction of a little of the historical, an emphasis of the value of particular methods, the correlation of the gross with the microscopic, the emphasis of surface form and markings in connection with tracts, and finally a real and not merely a perfunctory use of tracts as a basis for description. Such a use of tracts involves their introduction early in a course and their treatment as a ground plan or skeleton to which details can be related.

The only lack which I feel in the book is the absence of a few well chosen references. Such references are always appreciated by the best students.

Florence R. Sabin.

THE PANCREATIC DUCTS IN MAN, TOGETHER WITH A STUDY OF THE MICROSCOPICAL STRUCTURE OF THE MINOR DUODENAL PAPILLA

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TWELVE FIGURES

As ordinarily described in the text-books, there exist in the substance of the pancreas, two ducts; one, the larger and more constant, called the 'pancreatic duct' or 'duct of Wirsung,' and the other, smaller and comparatively inconstant, the 'accessory pancreatic duct' or 'duct of Santorini.' The main duct, beginning in the tail of the pancreas, courses from left to right through the body and neck to the head of the gland where it bends caudally, after receiving the accessory duct, and, traversing the head of the gland, perforates the duodenal wall to empty into the duodenum in company with the common bile duct; occasionally, however, apart from it. The accessory duct, on the other hand, is confined to the cephalo-ventral segment of the head which it traverses from its point of junction with the main duct to the minor duodenal papilla where it either empties into the duodenum or terminates blindly. This minor papilla in the duodenal mucosa bears a cephalo-ventral relation to the major papilla containing the ampulla of Vater and lies about 1.8 cm. from it. The one noticeable feature of the anatomical descriptions of these parts is the discordance of opinion concerning the terminal relations of the accessory duct.

In the year 1641, Moritz Hoffmann discovered the duct of the pancreas while working on a rooster and showed his findings to Wirsung, who the following year dissected the duct in the pancreas of a human body. In a letter to Jean Riolan, Jr., Professor of Anatomy in Paris, Wirsung gave to the world the first account of his important discovery.

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Wirsung had the duct reproduced on a copper plate from which but few copies were struck off. According to Choulant only two copies are known to be preserved. Schirmer (1893) saw one in the University of Strassburg and had a photolithographic reproduction of it made.

To Jo. Dominici Santorini belongs the credit for the first description of the accessory pancreatic duct and for the first representation approximating accuracy of the arrangement of the ducts in the adult human pancreas. He called attention to the existence of two papillæ in the duodenal mucosa and figured them in table 12 of his published work. In this connection, also, mention should justly be made of the name of Regner de Graaf, who previously had reported that, contrary to what had been the prevailing opinion, the pancreas might present two or even three ducts.

A complete list of the workers upon this particular problem in connection with the pancreas is lengthy; it includes such names as Vesling, who reported two ducts, apparently in lower animals, Thomas Bartholinus, Bernard Swalwe, G. Blasius, Johannes von Muralt, and Christianus Ludovicus Welschius. Now that the identity of the ducts was established, investigators began to report anomalous conditions of these passages; as Albrecht von Haller, Tiedemann, Mayer, and M. Bécourt. J. F. Meckel's was a significant statement in explanation of the causative factors involved in the production of the numerous anomalous conditions observed, *i. e.*, that atrophy of the duodenal end of the accessory duct was the developmental rule. A further list of workers at this period includes such names as Huschke, Jean Cruveilhier, and Sappey. Since the time of Claude Bernard, who in 1846 revived interest in the accessory duct, which had apparently been neglected, much attention has been given to the relation of the accessory duct to the main duct and to the duodenum. An incomplete list of the investigators thus engaged with the number of specimens studied is as follows: Bécourt, 32; Verneuil, about 20; Henle, Sappey, 17; Hamburger, 'mehr als 50'; Schirmer, 105; Schieffer, 10; Helly, 50; Charpy, 30; Letulle, 21; Opie, 100.

A study of the different methods employed by the investigators in their efforts to ascertain the condition of patency or occlusion of one or both ends of the accessory duct is of two-fold interest, because it illustrates the ingenuity of the workers, and, secondly, gives a probable explanation of the inharmonious results of their work.

For example, Claude Bernard used injections of metallic mercury which he forced into the main duct; Sappey, likewise working with mercury, ligated the ampulla and injected through the common bile duct. Schirmer, however, availing himself of Henle's objection to the use of mercury as an injection fluid for reason of its liability to burst through what might be a natural barrier at the blind duodenal end of the accessory duct, had recourse to the ingenious method of blowing air at a low pressure through the duodenal orifice of the main duct while the whole gland was submerged in water. Charpy used the injection method. His fluids were alcohol and some coagulable fluids, followed in some instances by the air injection method. Taking his cue from Charpy's comment

upon Schirmer's method in which the former said that it was well to dislodge by friction the mucous which might obstruct the ducts, Helly went one step farther towards accuracy by subjecting the minor papilla to a microscopical examination, after he had injected the ducts with a gelatin mass. His findings substantiated the previously advanced objections. Several times the injection mass broke down a natural barrier thus giving rise to the erroneous conclusion, had the microscopical examination not followed, that the channel in life had been patent. On the other hand, Helly found that several times a small accumulation of mucous was sufficient to completely block the accessory duct.

This present work comprises a study of one hundred specimens of adult human pancreas removed, with the exception of four derived from autopsies, from the bodies used in the regular dissecting courses in anatomy in the Cornell University Medical College at Ithaca, New York. The bodies had been embalmed with a mixture of equal parts of carbolic acid, glycerin, and 95 per cent ethyl alcohol. The ages of the individuals ranged from 21 to 95 years. There were 57 males and 21 females plus a series of twenty-two specimens from which the identification tags had been lost and consequently all data. Death in no instance had been caused by pathological processes localized either in the pancreas or in the duodenum.

The method followed in the examination of the specimens was as follows: the ductus pancreaticus was located by gross dissection, with the aid of a lens magnifying two diameters, in the neck of the gland where the pancreatic tissue overlies the superior mesenteric vessels. At this level the duct approaches the dorsal surface of the gland and is readily found usually about midway between the cephalic and caudal borders at a depth of 2 or 3 mm. in the gland substance. Once located, the duct was easily traced both towards the tail of the gland and towards the duodenum. In both of these regions it was found to lie nearer the dorsal than the ventral surface of the gland.

The junction with the accessory duct was most quickly reached by working along the ventral surface of the main duct beginning at the neck and proceeding towards the duodenum. In those anomalous instances where this duct could not be located by this method, the duodenum was opened along its right border and the position

of the minor papilla ascertained. Then, using this as a guide, the accessory duct was sought for in the glandular tissue cephalad to the level of the papilla. In those instances where no junction of the accessory duct and the main duct could be readily ascertained upon gross dissection, a ligature was passed around the duodenal end of the accessory duct at the point of perforation of the duodenal wall, and the main duct injected with a stain, either aqueous eosin or methylene blue. Regurgitation of the fluid into the accessory duct evidenced the presence of a communication between the two ducts. However, in no instance was the accessory duct injected with air or any fluid as a means of ascertaining the condition of patency of its duodenal termination.

The relation of the ducts to each other being thus established, the minor papilla entire, including the adjacent duodenal wall and a small portion of pancreatic tissue, was imbedded in paraffin, sectioned in series, and stained with the hæmatoxylin and eosin method. In four instances the accessory duct was of such a large calibre as to be readily followed through the papilla by gross dissection. In these few specimens the papilla was not sectioned and studied microscopically.

The relation of the main pancreatic duct to the termination of the bile duct was studied by gross dissection, while by slitting open both ducts their part in the formation of the major duodenal papilla was ascertained. The major papilla, however, was not sectioned or studied under the microscope.

In an investigation of this nature covering so much ground and productive of so many data it has seemed wise to present the facts of the problem in the topical order herewith listed.

1. The duodenal mucosa; its papillæ and intestinal valves.
2. The main pancreatic duct; course, tributaries, and drainage.
3. The duodenal termination of the pancreatic duct in the major papilla and its relation to the bile duct.
4. The accessory pancreatic duct; course, tributaries, and drainage.
5. The minor papilla; relation to the accessory duct and microscopical structure.

6. The relation of the main pancreatic duct to the common bile duct at the duodenal wall.
7. The bile duct and the major papilla.

1. The duodenal mucosa; its papillæ and intestinal valves

Attention was given to a study of the arrangement of the intestinal valves. These were exposed by laying open the duodenum along its convex border. The minor and major papillæ were present in every instance of this series of one hundred specimens. Locating the major papilla presented but little difficulty. On the other hand, it was occasionally only as the result of the most careful search that the minor papilla could be identified. It lay cephalad and on a plane ventral to the major papilla in ninety of the specimens. In eight instances the two papillæ were on the same vertical plane, the minor papilla being cephalad. Finally, in the two remaining specimens the minor papilla lay upon the same transverse plane with the other papilla but ventral to it. The fact is worthy of special mention that in no instance did the minor papilla occupy a position either caudal to the major papilla or dorsal to it. Separating these papillæ, the average distance, measured from center to center, was 2.0 cm. The shortest distance observed was 0.9 cm., and the longest 3.5 cm., and the mean distance 2.1 cm.

One specimen presented three papillæ; the minor papilla occupying the usual position relative to the major papilla and 2.3 cm. from it. The accessory papilla lay 1.0 cm. directly cephalad to the minor papilla. This third papilla had no pancreatic duct opening through it.

Notwithstanding the apparently hap-hazard and chance disposition of the smaller and incomplete mucosal folds in the vicinity of the papillæ, there could be identified in these specimens a marked conformity of the larger intestinal folds or valves to a fixed and entirely characteristic arrangement. In order that a more intelligible description might be made of these valves, I have divided them into two classes, *i. e.*, 'primary' and 'secondary.'

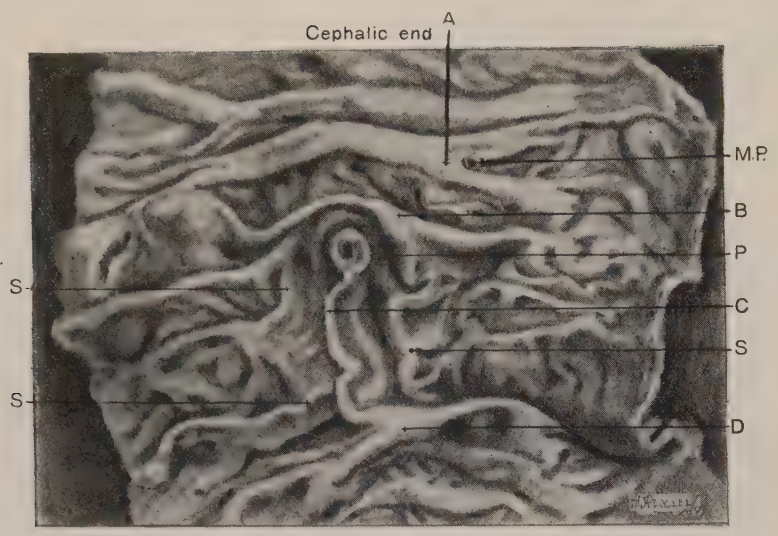


Fig. 1 (natural size) represents the typical distribution of the 'primary' and 'secondary' folds of duodenal mucosa in the region of the two papillæ in the descending portion of the duodenum. *M.P.* Minor papilla. *P.* Depression containing the major papilla with the orifices of the bile and the pancreatic duct. *C.* Plica longitudinalis duodeni. *A,B,D.* 'Primary' folds. *S,S,S,* 'Secondary' folds.

The basis of this classification is dependent entirely upon the size and constancy of the folds (fig. 1).

The minor papilla (*M.P.*) occupies a position upon a prominent 'primary' transverse fold or valve (*A*) and often at its bifurcation as represented in the drawing. It lies not on the ridge or crest of the valve but within the angle of bifurcation on the side of the fold. About 0.5 cm. caudal to this, a second, also 'primary,' fold (*B*) traverses the duodenal wall. Beginning at this second valve a prominent 'primary' longitudinal fold (*C*) proceeds caudally at a right angle and in the direction of the long axis of the duodenum. This is the 'plica longitudinalis duodeni' of the textbooks. Upon its summit and close to its cephalic extremity, in fact, overlapped by the fold indicated at (*B*), lies the major papilla presenting the orifices of the bile and pancreatic ducts. This plica passes caudally uninterruptedly across two or three 'primary' and 'secondary' (*S*) folds to terminate in another

'primary' transverse fold (*D*) located at the junction of the descending and transverse portions of the duodenum. Scattered among these 'primary' plicæ are many small 'secondary' folds (*S*), which have no definite or constant arrangement, which branch often, and which join or fuse with the larger folds at varying angles.

In addition to these features the observation was made upon thirty of the specimens that if the valves were disregarded, ironed out, so to speak, and merely the general contour of the duodenal wall considered, at the level of the major papilla a distinct bulging or hollowing of the wall towards the head of the pancreas was demonstrable. This feature was superadded to the constant dorso-ventral curvature of the duodenal wall and existed as a distinct entity. Furthermore, in sixty of the one hundred specimens, the major papilla occupied a small, localized, but, nevertheless, distinct pitting of the duodenal wall (*P*). This pitting was produced by simply a localized exaggeration of the general hollowing of the medial wall of the duodenum mentioned above. To the mind of the author, however, this hollowing was suggestive of a possible persistence of the original diverticulum from which in the embryo both the liver and the ventral pancreas developed.

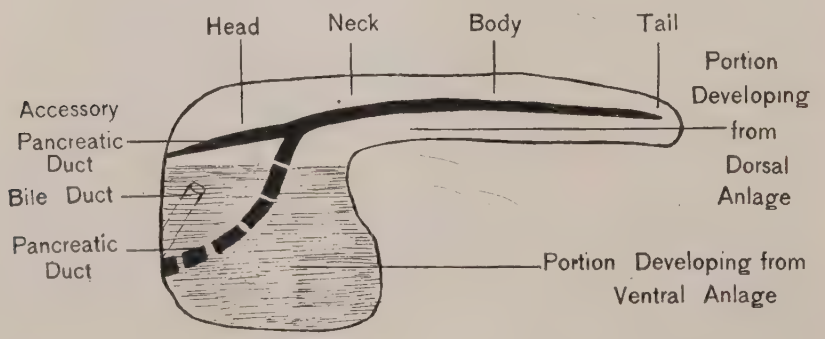
2. The main pancreatic duct; course, tributaries, and drainage

In order clearly to understand the arrangement of the ducts and their accessory features in the adult, our consideration must be turned to the embryology of the pancreas, which has engaged the attention of many workers, including the names of His, Phisalix, Zimmermann, Felix, Hamburger, Janosik, Jankelowitz, Swaen, Helly, Völker, Kollmann, Ingalls, and Thyng. According to the results of these investigators the human pancreas develops from the duodenum at the level of the hepatic diverticulum from two buds or anlages, one ventral, and the other dorsal, the former being in association with the hepatic diverticulum.

Diverse views are entertained at present concerning the duplicity of the ventral anlage, some maintaining that the bud is single from the first while others hold that at the beginning it consists of two lateral halves which subsequently fuse. The author has recently

published a paper descriptive of an unusual form of adult pancreas which possibly exemplifies a persistence of the earlier embryological condition of the primitive anlages.

Concerning the dorsal anlage we may say that contrary to what had been previously demonstrated by Hamburger, Felix, and Janosik, Thyng's studies seem to prove that "the dorsal pancreas arises from the intestine distinctly anterior to the hepatic diverticulum." From the dorsal bud the cephalic portion of the head and all of the neck, body, and tail of the pancreas develop, the ductus pancreatis dorsalis draining these portions. The ventral pancreas



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enclosing its duct, the ductus pancreatis ventralis, forms ultimately the caudal portion of the head of the gland (fig. 2).

The accompanying figure (2) represents diagrammatically the parts of the gland derived from the two anlages. The clear portion traversed by the heavy unbroken line is developed from the dorsal anlage, while the shaded portion is derived from the ventral anlage. The terms suggested by Thyng 'ductus pancreatis ventralis' and 'ductus pancreatis dorsalis' are particularly applicable from the standpoint of their embryological relations.

As development progresses, however, the ducts unite as is shown in the sketch, the duct of the dorsal anlage then undergoing a certain degree of atrophy at its duodenal end to thus produce the adult arrangement (see also fig. 3).

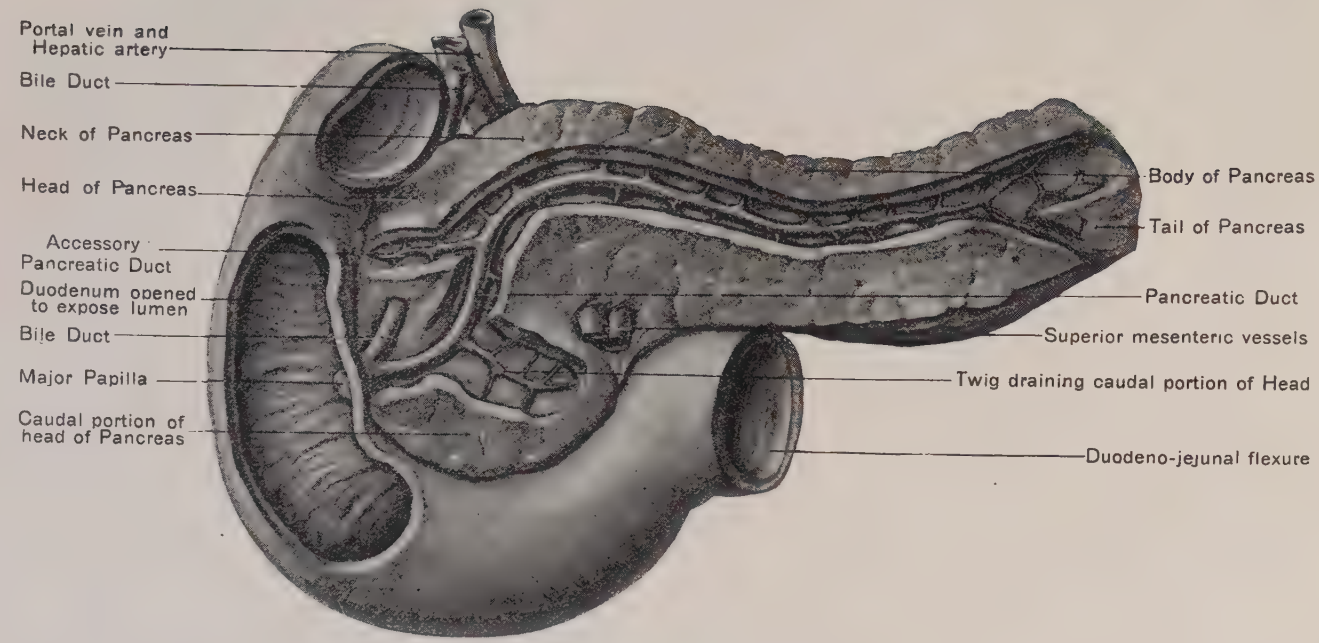


Fig. 3 represents the ventral surface of the pancreas and duodenum, with a portion of the glandular substance removed to show the disposition of the ducts as ascertained by this investigation. A window has been cut in the duodenum to expose the major papilla.

By keeping these facts of embryology in mind the anatomical findings of this investigation have a much clearer interpretation. The main duct was observed to begin in the tail of the gland through the convergence of a number of small duct radicles. It could not be demonstrated that these conformed to any particular arrangement. Pursuing a more or less tortuous course, the duct passed thence from left to right, traversing the glandular substance of the body of the pancreas and approximating the dorsal rather than the ventral surface of the gland. Furthermore, the duct lay nearer the cephalic than the caudal border of the body.

Upon arriving at the head of the gland, the main duct inclined somewhat abruptly caudally and dorsally with the convexity towards the right and approached the dorsal surface of the head of the gland. Reaching the level of the major duodenal papilla, the duct now ran almost horizontally to the right to join with the caudal aspect of the bile duct and empty with it into the major papilla (fig. 3).

The tributaries of the main duct in the body of the gland were observed to join that duct almost invariably at right angles and also to alternate with tributaries of the opposite side in the level at which they joined the main duct. These same features in turn characterized somewhat less noticeably, however, the radicles of these tributaries of the main duct. Only in the head of the gland was the conformity to these rules departed from. Here the tributaries were, occasionally, of some irregularity, first, in the angle of junction, and secondly, in the arrangement of the radicles.

Here also there existed one large unpaired trunk quite variable in appearance but well represented in fig. 3. This is the chief channel of drainage of the small lobe of the head (lobe of Winslow) which lies dorsal to the superior mesenteric vessels. Winslow in 1732, and later Charpy, called attention to its constancy. In four or five of the specimens dissected the last two tributaries joined this duct at the same level, and in such a manner and of such proportions as to appear to form a third pancreatic duct traversing the caudal segment of the head parallel to the main pancreatic duct. In no instances, however, was there any observ-

able direct communication between these twigs and the duodenum.

The main duct drained the whole of the body, tail, and neck of the gland, and in addition to these parts, in 66 per cent, or fifty of the seventy-six specimens studied for this purpose, the dorsal half of the head with nearly the whole of the caudal portion of the ventral half (fig. 2). This restricted the accessory duct to the ventro-cephalic portion in the immediate neighborhood of the minor papilla and to a small portion of the ventro-caudal segment. The main duct usually drained the whole of the region of the head adjacent to the neck. In four specimens the accessory duct drained the whole of the cephalic half of the head. In three instances the main duct was restricted to the dorsal and caudal portion of the head. In one other example the accessory duct drained nearly the whole of the head of the gland.

The outside diameter of the main duct, in those specimens with a normal arrangement of ducts (88), taken a few millimeters before it emptied into the duodenum and with the duct flattened out, averaged 3.25 mm. The mean diameter was 3.0 mm. In the body of the gland the duct averaged 3.0 mm. The smallest main duct measured 1.5 mm. and the largest 4.5 mm.

There were three specimens in the series which presented a rather unusual arrangement of ducts as represented in fig. 4. In these instances the main duct, descending towards the right into the caudal portion of the head, described a 'loop,' as shown in the figure, before finally proceeding horizontally to the major papilla. The accessory duct in these instances occupied its usual ventral and cephalic position and joined the main duct before the beginning of the 'loop.' In no instances was the main duct duplicated in the body of the pancreas as described by Bernard nor was there found the spiral disposition of the pancreatic duct as described by Hyrtl and figured in his Corrosion Anatomie.

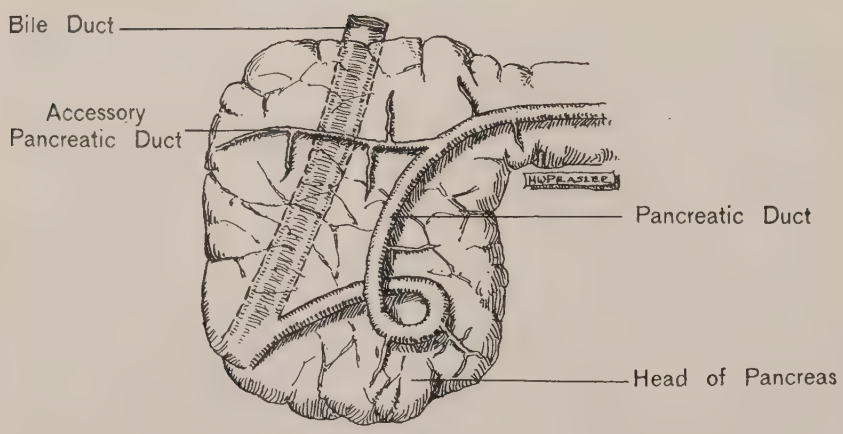


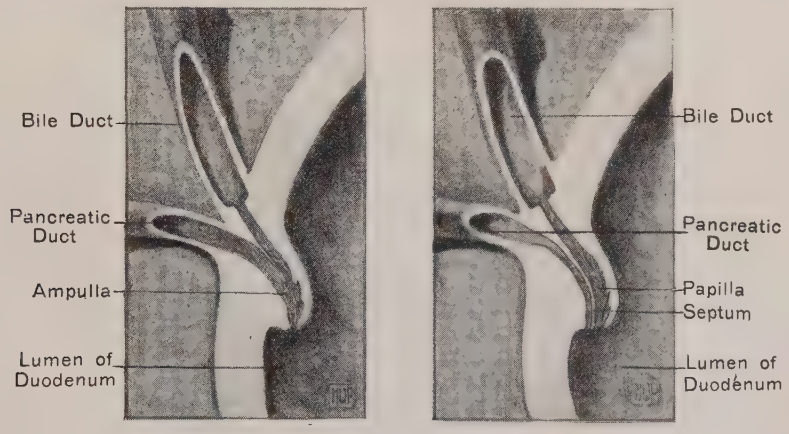
Fig. 4 A rough, schematic sketch of the ventral surface of the head of the pancreas showing the typical arrangement of the pancreatic duct in those specimens in which the 'loop' disposition prevailed.

3. The duodenal termination of the pancreatic duct in the major papilla and its relation to the bile duct

Ever since Bidloo first noted the papilla common to both the bile and the pancreatic duct, the relation of these two ducts to each other in the ampulla has been the subject of considerable investigation. Bernard and Laguesse each mentioned one specimen in which the main pancreatic duct opened into the duodenum apart from the orifice of the bile duct. Bécourt also recorded another instance. Schirmer reported twenty-two specimens (about 47 per cent) among forty-seven investigated in which a mucosal fold separated the orifices of the ducts in such a manner that a true ampulla did not exist. Opie examined one hundred specimens. In eleven instances no ampulla was present, the two ducts entering the duodenum separately. In the remaining cases the ampulla varied in length from less than 1 mm. to 11 mm., while in only thirty specimens did this measurement equal or exceed 5 mm. The ampullary orifice had an average diameter of 2.5 mm. Among twenty-one specimens which Letulle studied in only six was there a true ampulla.

The main pancreatic duct in this series of one hundred specimens approached the caudal aspect of the ductus choledochus to fuse with its wall before penetrating the duodenal wall (fig. 3). In two instances the main duct emptied into the caudal aspect of the bile duct at 1.3 cm. and 0.7 cm. respectively from the duodenal wall. Upon opening the ducts it was a noticeable fact that, notwithstanding the apparent fusion of the walls outside of the duodenum, the lumina did not unite until the duodenal wall had been perforated.

Fig. 5 represents diagrammatically the two classes into which the specimens reported and those studied in this investigation



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seem to fall. In *A* the walls of the two ducts are seen to fuse at the level of the duodenal wall. The lumina, on the other hand, do not fuse until the papilla has been entered. The thin mucous septum is shown separating the two ducts for a distance of at least one half of the papilla where the true ampulla can then be said to begin. Fig. 5, *B* represents the other general appearance noted, *i. e.*, complete isolation of the two ducts. The figure also gives a fairly good representation of the foliated appearance of the mucosa observed in the ampulla and mentioned at an earlier date by Bernard.

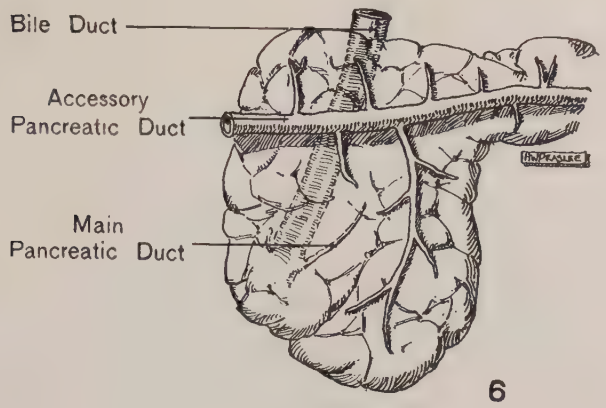
The distance from the mouth of the major papilla to the point of junction of the two ducts in the ampulla averaged 4.8 mm. (mean 4.0 mm.) in the ninety specimens dissected. In twenty of the specimens (about 22 per cent), there could be found no junction of the ducts, each opening side by side separately into the duodenum through the major papilla. This appearance is represented in fig. 5, *B*. A true ampulla was not present in these cases. In two specimens the distance observed was 0.5 mm. In twelve instances the partition was only 2.0 mm. from the mouth of the ampulla.

In but one pancreas was the duodenal end of the main duct occluded (fig. 6). The duct in this instance was a mere impervious twig which opened neither into the bile nor the accessory duct. The accessory duct drained the whole gland.

4. The accessory pancreatic duct; course, tributaries, and drainage

The accessory duct was found to be present in each of seventy-six specimens examined with that object in view. It was located entirely within the substance of the cephalo-ventral segment of the head (fig. 3), and pursued an arched course towards the duodenum. In no instance did it occupy a position wholly caudal to the main duct.

Invariably the accessory duct lay upon a plane ventral to that of the main duct. Two curves were described in its passage to the duodenum; the first of these, more pronounced and with its concavity cephalad, occupied the duct end, while the other the shorter of the two, was situated at the duodenal end with its concavity looking caudad. This condition, present in forty-two (64 per cent) of sixty-six specimens, is not clearly enough represented in fig. 3. In twenty-one specimens (31 per cent) the duct described a wide curvature with its concavity cephalad. Leaving the main duct it proceeded into the caudal portion of the head of the gland, then, turning to pass ventral to the main duct, emptied into the minor papilla. This appearance is represented in fig. 8. In the three remaining specimens (5 per cent) the usual curvatures of the duct were reversed, *i. e.*, a caudal concavity in the duct half with



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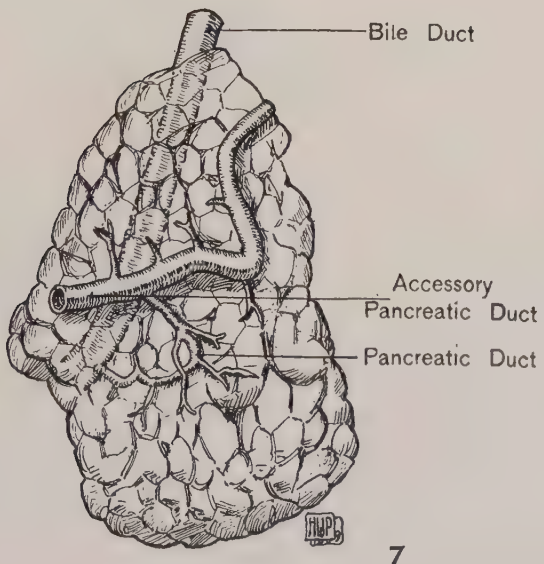

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Fig. 7 In this schematic sketch the ventral surface of the head of the pancreas is represented. Here the ducts are 'inverted,' *i. e.*, the accessory duct conveys most of the drainage from the neck, body, and tail of the gland into the duodenum. The main duct, occupying its usual caudal and dorsal position, is inferior in size to the accessory duct but joins the bile duct to empty with it through the major papilla into the duodenum.

a cephalic concavity at the duodenal end. Apart from the twenty-one specimens above noted, in forty-five (69 per cent) the duct was restricted to the cephalic and ventral segment of the head.

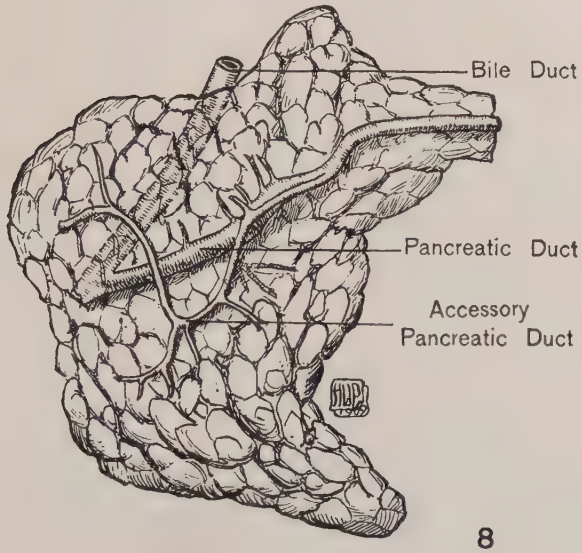
Charpy's work agrees with the results of this investigation regarding the part of the gland drained by the accessory duct. Opie, however, thought that the accessory duct drained "the anterior and lower part of the head" restricting for the main duct a smaller mass of parenchyma 'behind the larger lobe.'

In fifty-eight specimens (88 per cent) the duct approached the duodenum with diminishing calibre; in six specimens (9 per cent) the duodenal end was larger (fig. 7) while in two (3 per cent) both ends were of the same size. These figures, as would be expected, were compiled from those specimens in which the duct united with the main duct in the usual manner, namely, from sixty-six specimens. In ten other specimens where no demonstrable junction was present, the accessory duct naturally approached the duodenum with an augmenting calibre (figs. 9 and 10).

The outside diameter of the flattened accessory duct in these sixty-six specimens, taken at the point where it perforated the duodenal wall, averaged 1.2 mm. The smallest observed was 0.75 mm. and the largest 2.0 mm., with 1.0 mm. as the mean diameter of this end of the duct. Under the same conditions the other end of the accessory duct at its junction with the main duct measured 1.75 mm. with limits of 1.0 mm. minimum and 3.0 mm. maximum and with 1.5 mm. as the mean diameter.

In three other specimens, however, the maximum diameters observed at the duodenal end were 2.5 mm., 3.0 mm., and 3.5 mm. respectively, but these were instances of inversion of the ducts, *i. e.*, the main duct was inferior in size to the accessory duct as represented in figs. 7 and 9.

These facts bear out Meckel's statement that in the fœtus the two pancreatic ducts possess the same calibre, but as development progresses the accessory duct undergoes a natural atrophy at its duodenal end. This fact was also noted by Bernard and verified still later by Schieffer upon five human fœtuses from 7.5 to 9 months of age.



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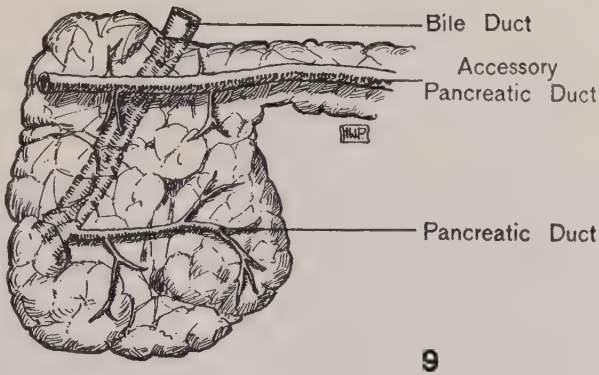

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Fig. 8 This sketch represents the ventral surface of the head of the pancreas showing the accessory duct passing through the caudal portion of the head.

Fig. 9 represents a condition present in five specimens of the seventy-six dissected (6.5 per cent). The ducts do not unite. The accessory duct, larger than the main duct, drains the whole of the body, tail, neck, and cephalic half of the head. This is a persistence of the embryonic arrangement of ducts. To these ducts the terms ductus pancreatis ventralis for the main duct and ductus pancreatis dorsalis for the accessory duct are particularly applicable.

In ten of seventy-six specimens (13.2 per cent) the accessory duct failed to join with the main duct (figs. 9 and 10). The junction in the other sixty-six specimens, or 86.8 per cent of cases, was found invariably in the head close to the neck of the gland (fig. 3). Among these latter the accessory duct fused with the ventral surface of the main duct in twenty-five (38.0 per cent), with the caudal surface in twelve (19.0 per cent), the duct passing ventral to the main duct; and with the cephalic surface in twenty-nine specimens (43.0 per cent).

5. The minor papilla; relation to the accessory duct and microscopical structure

The minor papilla was present in each of one hundred specimens examined. As a means of studying more accurately the relation of the accessory duct to the minor papilla, forty-six out of a total series of fifty specimens were subjected to a microscopical examination without first having been injected as a means of ascertaining the condition of patency of the duodenal end of the duct. A block of tissue comprising the papilla and the duodenal wall with the adjacent pancreatic substance was imbedded in paraffin, sectioned in series in thicknesses varying from 12 to 40μ and stained with hæmatoxylin and eosin.

Forty-one specimens (82 per cent) demonstrated a patent accessory duct. In five (10 per cent) the duct was closed, terminating blindly at the papilla. It seems needless to say that in these last specimens the accessory duct communicated with the main duct through an ample orifice. A feature especially worthy of mention was the abrupt manner in which the accessory duct in these five instances became constricted from an ample lumen to one of capillary dimensions and then terminated abruptly at the papilla. This abrupt dwarfing of the duct was no exceptional feature confined to these five isolated specimens. It was the rule rather than the exception. In brief, as was frequently verified, amplitude of calibre was no criterion of patency. In the four remaining specimens of the series of fifty selected (8 per cent), the patency of the accessory duct was so manifest as to be demon-

strable upon gross dissection. In these, therefore, no microscopical examination was made. This gives, then, among fifty specimens examined, a total of five (10 per cent) which did not communicate with the duodenum. Further, in six other specimens the accessory duct did not unite with the main duct, giving, therefore, a total percentage of practical importance of eleven specimens out of fifty (22 per cent) in which fluid could not pass from the main duct into the duodenum through the accessory duct.

The shape of the papilla was uniformly rounded or conical with a diameter averaging 2 mm. and an aperture quite variable,

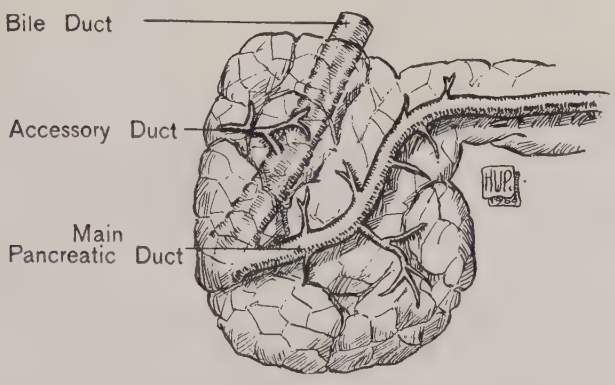


Fig. 10 shows an arrangement found in five specimens (6.5 per cent) of the seventy-six dissected. The accessory duct is isolated and smaller than the main duct. It drains but a small region in the immediate neighborhood of the minor papilla, through which it opens into the duodenum.

most often not visible to the unaided eye. The epithelial covering did not differ in appearance from that found in the rest of the duodenum (fig. 11, *E*). The mass of the papilla was composed of a core (*C.C.*) This core, imbedded in the mucosa and submucosa of the gut and extending obliquely from the muscularis (*M*) to the epithelial covering of the papilla (*E*), consisted of a supporting framework of dense connective tissue, and appeared as a constant factor in the structure of the papilla. It was present when the accessory duct failed, indeed, its size, which contributed largely to the proportions of the papilla, seemed less referable to the presence of the accessory duct than to the

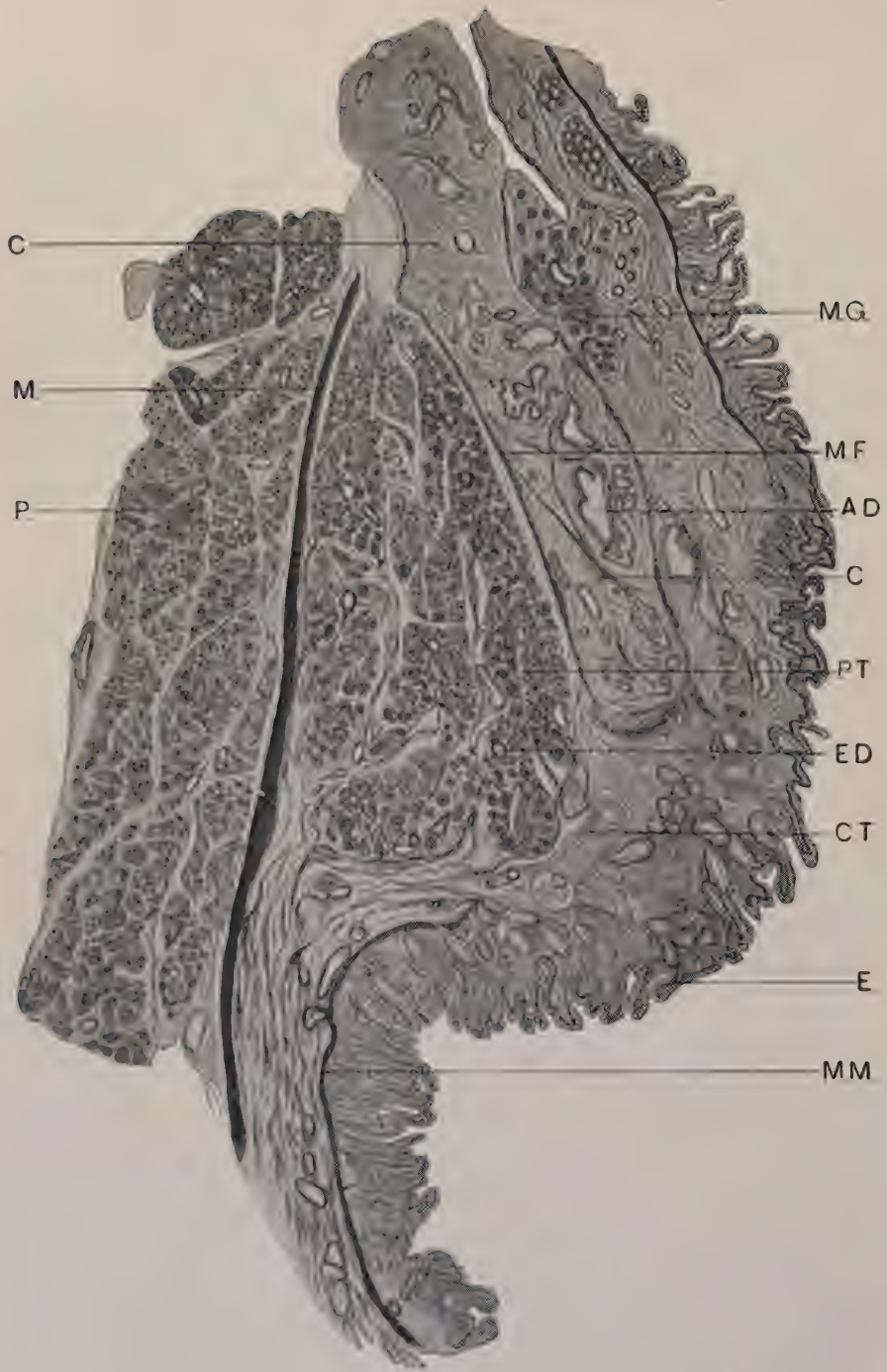


Fig. 11 (magnified 18 diameters) A longitudinal microscopical section of the minor duodenal papilla showing the passage of the accessory duct through the 'core' of connective tissue.

quantity of mucous glandular tissue enclosed within its stroma. The prominent features, then, of the papilla were this core of dense connective tissue containing many smooth muscle fibres (*M.F.*) and enclosing much mucous glandular tissue, with the accessory duct (*A.D.*) traversing the middle of its substance. Its whole appearance was strongly suggestive, however, of functional regression remindful of Meckel's observation regarding the developmental atrophy of the duodenal end of the accessory duct.

The accessory duct (*A.D.*) passed directly from the pancreatic tissue (*P*) of the head of the gland, which accompanied it up to the duodenal wall, through both layers of muscular tissue (*M*). Entering immediately into the substance of the core, it passed through the middle of its stroma to open finally into the duodenum. At the level of perforation of the duodenal wall, it underwent an abrupt caudal bending. The angle of this flexure, as previously noted by Helly, varied from 20° to 30°. In thirty-seven of the fifty specimens (74 per cent) the duct passed in a caudoventral direction through the papilla; in six specimens (12 per cent) it curved caudodorsally; and in the remaining seven specimens (14 per cent) horizontally ventral. Occasionally it was noted that the fibres of the muscularis formed a sphincter-like ring around the duct at the level where it perforated the duodenal wall.

There was no difficulty experienced in tracing the accessory duct through the pancreatic tissue which accompanied it up to the duodenal wall. The lumen was direct, uniform, and either gradually enlarging or diminishing in calibre. Once that the muscularis was perforated, however, the appearance of the duct was transformed to a remarkable extent. The lumen now became tortuous and irregular, dilating and narrowing, and, at times, branching to reunite farther along in its course. To add to the complexity of this arrangement the association with the duct in the core of numerous mucous glands, whose individual or combined ducts either opened directly into the accessory duct or independently into the intestine, rendered the tracing of the lumen of the duct particularly difficult.

The amplitude of lumen of the accessory duct as it approached the papilla offered no trustworthy suggestion of its condition of

patency or occlusion in the core. Oftentimes a duct with the largest calibre dwarfed instantly to capillary dimensions upon entering the core. On the other hand, occasionally the smaller and most unpromising ducts traversed the core with a direct, unsinuous, and even enlarging lumen. In six specimens (12 per cent) the lumen of the accessory duct gradually increased in size as it traversed the papilla towards the epithelial covering. In ten specimens (20 per cent) the lumen sustained a pronounced diminution in calibre, while in the remaining thirty-four cases (68 per cent) the duct was so tortuous and irregular as to make it impossible to say whether there was an actual increase or a reduction in size.

In the five instances in which the accessory duct did not communicate with the duodenum, the duct was found to have perforated the muscularis. In the core immediately adjacent to the muscular coat, however, it suddenly underwent a diminution in calibre and terminated blindly in the connective tissue of the stroma of the core (*C*). In some of these specimens the strands of connective tissue separating the duct lumen from that of the adjacent mucous glands were so delicate that it seemed possible and, indeed, quite probable that they could be broken down by an injection mass even under the lightest pressure, thus giving rise to erroneous conclusions as to the condition of patency of the duct. Thus was confirmed both Henle's and Helly's objections to injection methods.

In those instances where the duct was comparatively ample and the lumen could be followed with little difficulty through the papilla, the mucous glandular, and pancreatic tissues played only subsidiary parts in the formation of the core and but little muscular tissue was discernible. In the majority of instances, however, the duct, being constricted, formed but a small part of the core. In these specimens the connective tissue and muscular stroma were very prominent. In these, too, aside from the epithelial lining of the lumen, there was no distinct wall to the duct. The true wall ceased where the duct perforated the muscular coat of the duodenum.

The duodenal orifice in the instance of the small ducts appeared like that of an intestinal gland, the lumen proper of the duct, indeed, seemingly, opening into the fundus of the tubule and the side walls not differing from those of the usual intestinal gland. Larger ducts, however, opened through what appeared to be several fused tubules. This orifice occurred either upon the caudal slope or upon the summit of the papilla, seldom upon its cephalic aspect.

Many glands (*M.G.*), which from general appearances seemed to be mucous in character, were found associated with the accessory duct. The characteristic staining of mucous glands could not, however, be obtained in the instance of these glands owing, doubtless, to their imperfect fixation. Kölliker noted the occurrence of these glands in the walls of the larger ducts of the pancreas apart from the papillæ.

These glands occurred in large, irregular, spherical groups situated either with the accessory duct within the core or immediately outlying it in the loose connective tissue of the papilla. The ducts of those glands situated within the core opened through irregular channels into the accessory duct. Those located near the epithelial extremity of the core imbedded in the connective tissue of the papilla opened directly upon the surface of the duodenal mucosa, while those farther removed from the epithelium emptied by longer channels, either into the accessory duct or upon the surface of the mucosa. The presence or absence of the accessory duct did not seem to influence the number of these glands so much as might be expected. In the five specimens of occlusion of the duct, they opened either directly upon the surface of the mucosa or indirectly through a lengthy, tortuous channel which occupied the usual position of the accessory duct in the core. When the duct was very large and patent the mucous glands were fewer in number and much more scattered. No instances were found where the glands were entirely absent.

In confirmation of Helly's and of Opie's earlier observations, small masses of pancreatic tissue (*P.T.*) were found in two situations, first, within the core close to the duodenal muscularis; secondly, in the loose connective tissue of the papilla usually

upon the caudal aspect of the core. This pancreatic tissue differed from the tissue of the pancreas itself only in the distribution of the supporting connective tissue, the latter occurring in thick, well-marked septa isolating the lobules and acini from each other. The ducts from the acini united into larger trunks which emptied either directly into the accessory duct or independently upon the epithelial surface of the duodenum.

The unstriped muscle tissue (*M.F.*) contributed largely to the thickness of the septa of the core. The fibres were scattered either parallel to the long axis of the core or were disposed circularly around some of the tubules. The amount of muscular tissue was greater towards the muscularis side of the papilla but few fibres reaching the level of the intestinal glands. There could not be observed any relation between the condition of patency or occlusion of the accessory duct and the number of these fibres.

Claude Bernard thought that the papilla was contractile.

The relation of the muscularis mucosæ (*M.M.*) of the duodenal wall to the tissue of the core could not be ascertained in every instance. In some specimens it was continuous with the muscular tissue of the core. In many others, however, it could be clearly seen that there was no continuity of this structure with that in the core.

The following pages present a tabular compilation of all of the work which has been done upon the features presented in this problem.

The minor papilla

	PRESENT	ABSENT
Schirmer	103	1
Helly	47	3
Charpy	29	1
Verneuil	20	0
Baldwin	100	0

Thus it will be seen from the above that in about 98 per cent of specimens the minor papilla is present.

But four specimens of three papillæ have been reported:

Schirmer 1
Letulle 1
Rollestin and Fenton 1
Baldwin 1

None of these accessory papillæ have been studied microscopically. The papillæ are of possible interest in two ways, first, because of the occasional bifid character of the ventral anlage, and, secondly, because of the occasional appearance of a third duct in the caudal region of the head.

The accessory duct

	PRESENT	ABSENT
Schirmer	101	3
Charpy	29	1
Helly	50	0
Verneuil	20	0
Santorini	?	0
Bernard	?	0
Hamburger	50+	0
Sappey	17	0
Opie	100	0
Baldwin	76	0
About	443	4

Complete absence of the accessory duct according to these figures seems to be a rare anomaly since it occurs in less than 1 per cent of specimens.

Condition of accessory duct at duodenal end. With microscopical method

	PATENT	CLOSED
Helly	40	10
Baldwin	45	5
Total	85	15

With injection method

Schirmer	85	19
Charpy	9	21
Opie	79	21
Verneuil	20	0
Sappey	16	1
Total	209	62

According to the microscopical method, 15 per cent of ducts are occluded; with the injection method about 23 per cent are closed at the duodenal end.

Relation of main to accessory duct

	JUNCTION	NO JUNCTION
Opie	90	10
Duval	?	1
Helly	48	2
Charpy	28	2
Schirmer	97	7
Verneuil	20	0
Baldwin	66	10
Total	349	32

According to these figures a junction between the main duct and the accessory duct is to be expected in over 90 per cent of specimens.

The accessory duct is larger than the main duct

	SPECIMENS EXAMINED	INVERSION
Schirmer	104	3
Charpy	30	3
Bernard		1
Morel and Duval	?	1
Opie	100	11
Bimar	?	1
Moyse	?	1
Baldwin	76	3
Total	310	24

Distance between major and minor papillae

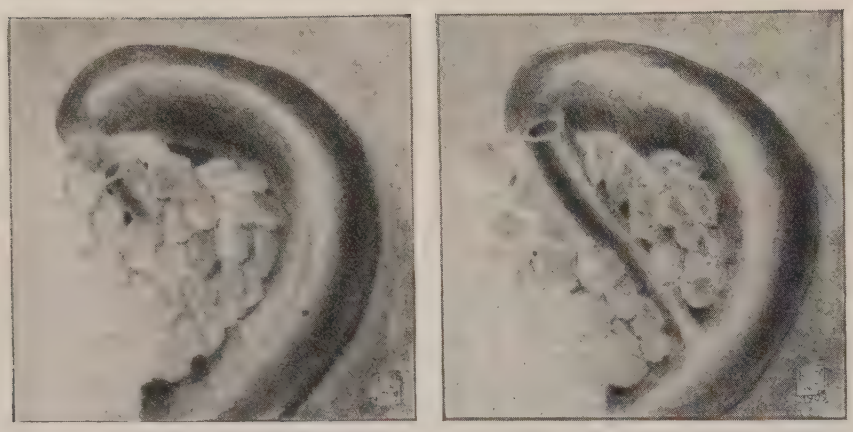
	NUMBER EXAMINED	AVERAGE	LIMIT
		cm.	*cm.*
Bernard	?	3.5	(2.0–4.0)
Schirmer	104	2.5–3.5	
Letulle	21	1.8	(1.0–3.5)
Baldwin	100	2.0	(0.9–3.5)

6. *The relation of the main pancreatic duct to the common bile duct at the duodenal wall*

Schirmer mentioned eleven instances among a series of forty-seven specimens in which the pancreatic duct opened into the bile duct and also fourteen instances in the same series in which the bile duct opened into the pancreatic duct. In these cases the single conjoined duct was the only one entering the ampulla of the papilla. Verneuil seemed to believe that usually the pancreatic duct received the bile duct and that, accordingly, the ampulla of the papilla belonged to the pancreatic duct. The main duct did not fail in any of the ninety specimens of my series, in one, however, it was occluded at its duodenal end. Helly saw one instance where the main duct was absent; Schirmer, four; Cruveilhier, one; Charpy, one. (See topic 3, page 208.)

Occasionally the common bile duct opens into the duodenum in company with the accessory duct. No such instance was found in my series. Schirmer mentions five. Tiedemann mentions one case where both pancreatic ducts emptied separately into the duodenum apart from the common bile duct.

	THE DUCTS JOIN TO FORM AN AMPULLA	NO JUNCTION
Bernard	?	1
Laguesse	?	1
Schirmer	25	22
Opie	89	11
Letulle	9	12
Baldwin	70	20
Total	193	67



A B

Fig. 12 (dorsal view) represents the two conditions of the bile duct. In *A* the duct passes through the tissue of the head of the pancreas. In *B* the duct grooves the head of the gland but is not entirely surrounded by pancreatic tissue.

In about 25.8 per cent of specimens the ducts open separately into the duodenum. In 74.2 per cent the ducts have a common ampulla.

7. The bile duct and the major papilla

As an unavoidable adjunct to this study of the ducts of the pancreas the relations of the terminal or pancreatic portion of the bile duct were considered in this series of one hundred specimens. The duct ran invariably caudally towards the median surface of the second portion of the duodenum lying dorsal to the head of the pancreas and producing a furrow upon that surface. In no instance did it pass, as was observed by Helly, in a groove between the duodenum and the pancreas. In 80 per cent of the specimens the pancreatic tissue completely surrounded the duct for a distance varying from 0.5 cm. to 5.0 cm. In 5 per cent of specimens the duct received a partial investment without being entirely enclosed by glandular tissue, while in the remaining 15 per cent of specimens the bile duct grooved but was not covered by the tissue of the head.

The lumen of the bile duct underwent a marked contraction at the duodenal wall before its junction with the main pancreatic duct (fig. 5). Cephalad to this level a distinct bulging or ampulla was noticeable. The difference in calibre between these two adjacent portions was less appreciable upon the external surface of the duct than upon the internal. The outside diameter of the bile duct at the level of its perforation of the duodenal wall was 5.4 mm. in the one hundred specimens, that of the ampulla of the duct averaged 6.4 mm. The largest bile duct observed measured 15.0 mm. and the smallest 3.0 mm. This gives 6.0 mm. as the mean diameter of this duct. These measurements are outside diameters taken with the duct flattened out.

Letulle and Nattan-Larrier reported nineteen specimens in which the common bile duct traversed the head of the gland, often only a thin strip of pancreatic tissue separating the duct from the duodenum. Usually the glandular tissue extended a distance of only 2 or 4 cm. along the duct wall. The bile duct underwent a diminution in size in the last centimeter averaging 8 to 9 mm. in diameter. Several were from 12 to 14 mm.

O. Wyss found five specimens among twenty-two in which the terminal portion of the common bile duct penetrated the head of the gland. Helly studied forty specimens, in about half of which the duct lay in a canal of pancreatic tissue.

Judging from the results of these investigations, we should expect to find the terminal portion of the bile duct imbedded in pancreatic tissue in about 65 per cent of specimens.

Because of the nature of the material used in this investigation it was found impossible to use the whole series of one hundred specimens in the several portions of this problem. As many of them as were suitable, were utilized, however, with the result that a smaller number of specimens had to be reported upon in many of the essential features of the problem. This accounts, therefore, for the somewhat confusing use of varying numbers of specimens.

In conclusion I wish to express my sincere appreciation of the valuable advice and assistance given by Professor Gage, Dr. Kerr, and by Dr. Kingsbury in the preparation of this paper and for the numerous courtesies shown by their departments.

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THE OCCURRENCE IN MAN OF DOUBLE GANGLIA UPON THE DORSAL ROOTS OF THE SPINAL NERVES

HERBERT N. T. NICHOLS

From the Anatomical Laboratory, University of Michigan

FIVE FIGURES

Nearly all of the more recent standard text books of anatomy that I have examined, as well as the earlier editions of some of these works, speak of the occurrence sometimes in the lumbar and in the sacral regions of dorsal root ganglia that are partially separated into two divisions. Most of these anatomies also mention small accessory ganglia, *ganglia aberrantia* of Hyrtl, lying upon the dorsal root between the main ganglion and the cord, particularly in the upper cervical region. The literature dealing with the occurrence of double ganglia upon the dorsal roots of the spinal nerves is, however, very meagre. Davida[1] published an article describing double ganglia in the lumbar and sacral regions. He gives references to no other articles. He examined the lumbar and sacral ganglia from three cadavers. The ganglia from one of the cadavers he describes minutely, the other two not so minutely. In two of the cadavers he found several double ganglia, while in the other he also found a three lobed ganglion. A little later Rattone[2] published an article describing the occurrence of ganglion cells scattered along the dorsal roots of all the spinal nerves. He refers to the earlier work of Hyrtl, and calls

[1]Davida: 1880 Ueber die Multiplicität der Lumbal- und Sacral-Spinal-ganglien. Centralblatt für die medicinischen Wissenschaften. Vol. 18, P. 465.

[2]Rattone: 1884 Sur l'existence de cellules ganglionaires dans les racines postérieures des nerfs rachidiens de l'homme. Internationale Monatsschrift für Anatomie und Histologie. vol. 1.

attention to three treatises upon anatomy[3] in which aberrant ganglia are mentioned. He speaks of having seen a double lumbar ganglion. "En 1879, sur certaines pièces de système nerveux rachidien, (pièces conservées dans le Museum d'Anatomie normale de l'Université) et que j'ai préparées selon la méthode proposée par Giacomini, Giacomini lui-même me faisait remarquer la duplicité d'un des ganglions lombaires." He also refers to the work of Davida. Rattone states that these are the only articles he found that had any bearing on his investigations.

The occurrence of double ganglia upon the dorsal roots of the spinal nerves was brought to our attention during the course in dissection, and in view of the meagre literature upon the subject, at the suggestion of Professor Streeter, I undertook a more careful study of the ganglia and spinal nerve roots with regard to the details of their gross anatomy. As a result of this study I have been able to establish an unexpected frequency of the doubling of spinal ganglia. It does not occur in the cervical or thoracic region, but in the lumbo-sacral region it is very common. The tendency to division of the ganglion begins at the first lumbar and reaches its maximum at the third, fourth and fifth lumbar, where partial or complete division occurs in from 36 to 44 per cent of the cases. The frequency then quickly diminishes and the phenomenon altogether ceases at the third sacral.

In the anatomical laboratory[4] at the University of Michigan the routine in dissection is arranged so that a complete study of all of the spinal ganglia is possible. After the dissection of the long muscles of the back and the identification and removal of the shorter ones, the spinous processes and laminae of the vertebrae are removed with chisel and hammer. This lays bare the dura mater of the cord. To expose the portions of the roots and ganglia lying in the intervertebral foramina the articular processes and surrounding bony parts of the vertebrae are cut away with bone pliers. After completely exposing the cervical

[3] W. Krause: 1881 Allgemeine und mikroskopische Anatomie. Hanover 1876 Henle; Handbuch der Nervenlehre des Menschen, 1879; page 505. Schwalbe Lehrbuch der Neurologie, Erlangen; page 802.

[4] Streeter: 1909 Laboratory guide in anatomy.

and brachial plexuses above, parts of the sacrum and of the ilium are removed, having reflected the gluteus maximus muscle, exposing the whole sacral plexus and its branches. Any adipose and connective tissue that still conceals the ganglia and the early course of the nerves is dissected off, thus laying bare the formation and the fisrt part of the course of all the spinal nerves, making a careful study of them possible.

Last year during two of our dissection periods I saved out from the cadavers for more careful examination as many of the roots and ganglia of the spinal nerves as the students had successfully laid bare in dissecting away the surrounding bony parts. The cadavers from which the ganglia were taken were in the main elderly white males. Their average age was fifty-five years. There were two or three females and two or three negroes in the lot. In the removal of the specimens for careful examination all ganglia from the same region and from the same segment of the cord from all of the bodies were placed together. No distinction was made between right and left, and no attempt was made to keep those of one cadaver separate from those of another. The ganglia with their accompanying ventral and dorsal roots I dissected in water under a hand lens. Several ganglia were embedded in paraffin and cross sections prepared for the study of the finer details in the formation of the capsules. Examples in this way were studied of both incomplete and completely divided ganglia.

In the accompanying table 1, there is shown the number of ganglia examined at each respective level. No attempt was made to include the first cervical ganglia on account of their irregularity and retrogressive tendency. Also on account of their small size I did not study the last sacral and the coccygeal ganglia.

Examination of the table immediately shows that the phenomenon which we are sudyiag is confined to the lumbar and sacral regions. The occurrence of the tendency to division describes a curve beginning at the level of the first lumbar nerve. The curve then abruptly ascends and reaches its highest point at the third lumbar. Its summit extends from the third to the fifth

lumbar where it abruptly drops, finally disappearing at the level of the second sacral nerve. In this table there are included under one heading both partially and completely divided ganglia, but as will presently be seen the curves would be similar if complete and incomplete divisions were plotted separately.

TABLE 1

Occurrence of partial or complete division of spinal ganglia

REGION	NUMBER OF GANGLIA EXAMINED	PARTIAL OR COMPLETE DIVISION
Cervical 2	21	0
3	23	0
4	31	0
5	20	0
6	20	0
7	20	0
8	20	0
Thoracic 1	20	0
2	14	0
3	19	0
4	17	0
5	20	0
6	20	0
7	14	0
8	16	0
9	19	0
10	14	0
11	18	0
12	16	0
Lumbar 1	31	1 (3.2 per cent)
2	42	9 (21.4 ")
3	59	26 (44. ")
4	56	21 (37.5 ")
5	52	19 (36.5 ")
Sacral 1	41	3 (7.3 ")
2	45	1 (2.2 ")
3	34	0
4	7	0

GROSS APPEARANCES

In the lumbar and sacral regions the ganglia that were single were mainly oval in shape; were flattened dorso-ventrally; had a greater diameter from end to end than from side to side, and varied in shape and size. The upper lumbar were smaller than the lower lumbar and the upper sacral; while the lower sacral were the smallest. The upper lumbar were rounded and more spherical than were the lower lumbar and the upper sacral; while the lower sacral as they decreased in size became more and more fusiform in shape. The fibres of the posterior root left the central end of the ganglion principally in two main bundles. Among these single ganglia there were some that showed, as it were, an unsuccessful attempt to become double by the formation of

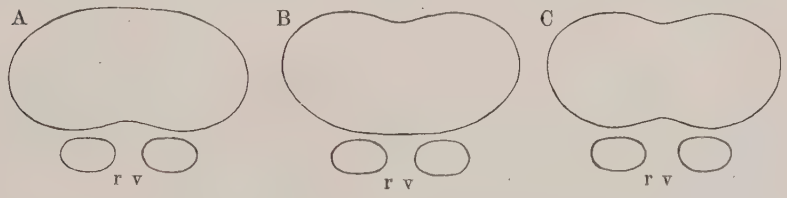


Fig. 1 Diagrammatic cross section through ganglia showing an indentation upon the ventral aspect (*A*), upon the dorsal aspect (*B*) and upon both the ventral and the dorsal aspects (*C*). Note the two divisions of the ventral root (*rv*) lying upon the ventral aspect of the ganglia.

a shallow longitudinal furrow upon either the ventral aspect or the dorsal aspect or upon both the ventral and dorasl aspects. Fig. 1 shows the outline of a cross section through these varieties of ganglia that have an early aborted cleavage. In several instances there was shown at the end of the ganglion the beginning of a division which was more or less hidden from view by the entering or leaving bundles of nerve fibres. In cases of this sort there was a fissure or notch at the end of the ganglion, as shown in fig. 2, which made a cleft that passed in an antero-posterior plane for a short distance into the ganglion, extending inward for less than one-fourth of its length.

The accompanying table 2 gives a condensed statement of the degrees and varieties of incomplete division that were met with

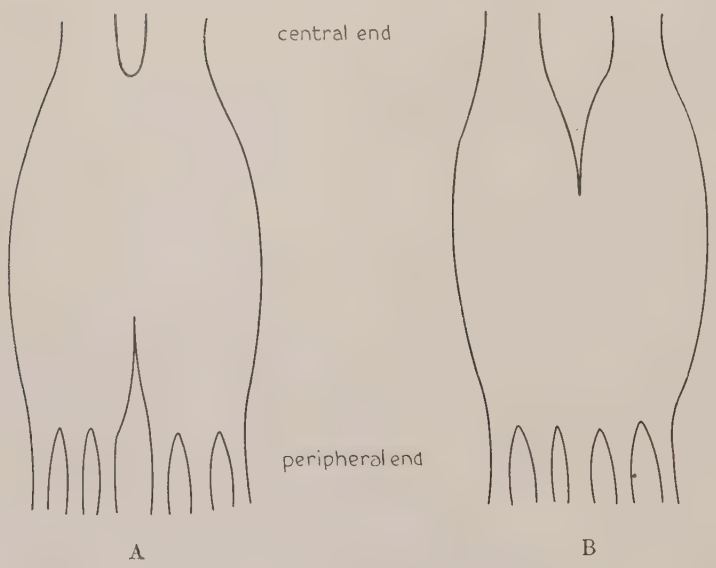


Fig. 2 Diagrammatic longitudinal section through ganglia showing complete cleavage for one-third their length, (*A*) at the central end and (*B*) at the peripheral end. Note the numerous bundles of entering fibres at the peripheral end and the two bundles of emergent fibres at the central end.

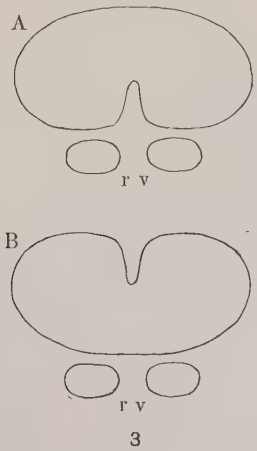
which were as will be seen diverse and varied. They are classed into several groups according to their characteristics as is briefly summed up in the different divisions and subdivisions of the table. It will be noticed that the different stages of division or duplicity very readily fall into a series of an ascending, ever increasing degree of cleavage. Ganglia that are classed as single, with the modification that they show a beginning division, start the series, which passes up through the different gradations of cleavage till it reaches the stage where the ganglionic tissue is all but completely separated into two distinct parts.

In many instances border-line ganglia were found which could be classed either under single ganglia showing a tendency to division or under double ganglia in which the division was incomplete.

In some of the ganglia of this class, (table 2, *2*) the ganglion instead of being of a regular oval shape, was, in the main, oval,

but had, at the peripheral end on one or on both aspects, a bulging enlargement which was separated from the rest of the ganglion, not by a fissure, but by only a shallow groove or aborted division cleft. This bulging or protuberance, as we may call it, had a greater dorso-ventral diameter than did the rest of the ganglion. Furthermore, the bulging protuberance did not extend clear across the entire breadth of the ganglion, but occupied only one-third to two-thirds of its breadth. Also the protuberance, in some of the cases, extended considerably farther toward the periphery than did the rest of the ganglion.

A few of the ganglia (table 2, *3*) showed sufficient indications of divisions at both ends and on the ventral aspect, or at both ends and upon both ventral and dorsal aspects to entitle them to classification among the ganglia that showed an incomplete separation of ganglionic tissue. They could no longer be regarded as single ganglia. Such ganglia before their dissection had a marked appearance of duplicity. In one ganglion of this sort



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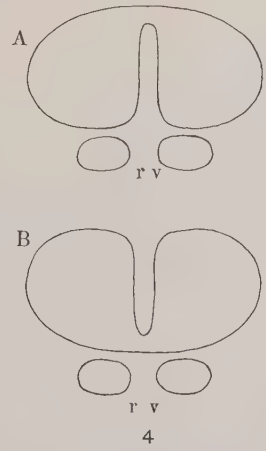

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Fig. 3 Diagrammatic cross section of ganglia showing a partial cleavage, (*A*) upon the ventral aspect, and (*B*) upon the dorsal aspect. The two divisions of the ventral root(*rv*) show upon the ventral aspect.

Fig. 4 Diagrammatic cross section of ganglia showing a cleavage extending nearly through the ganglionic tissue, (*A*) from the ventral aspect, and (*B*) from the dorsal aspect. The two divisions of the ventral root (*rv*) show upon the ventral aspect.

TABLE 2

Degrees and varieties of incomplete division

	REGION AND LEVEL FROM WHICH TAKEN		L. 1	L. 2	L. 3	L. 4	L. 5	S. 1	S. 2	S. 3	S. 4
1	Classed as single, but showing a slight furrow on	Ventral aspect		2	3	7	4	1	2		
		Dorsal aspect			1	1	1				
		Both ventral and dorsal aspects	2	1			1				
2	Two lobes indicated, one being a rounded eminence above level of other without division fissure between. Rounded eminence occurs at peripheral end on	Ventral aspect					1				
		Dorsal aspect									
		Both ventral and dorsal aspects				2					
3	Division indicated	At both ends of ganglion and on ventral aspect				2					
		At both ends of ganglion and on both ventral and dorsal aspects			1	2	1				
4	Complete cleavage at central end for	Less than one-fourth length of ganglion, but classed as single			1						
		One-fourth to one-third length of ganglion									
		One-half length of ganglion			2		1				

TABLE 2—CONTINUED

	REGION AND LEVEL FROM WHICH TAKEN		L. 1	L. 2	L. 3	L. 4	L. 5	S. 1	S. 2	S. 3	S. 4
5	Complete cleavage at peripheral end for	Less than one-fourth length of ganglion, but classed as single		1	4	3	2				
		One-fourth to one-third length of ganglion			2	2	2				
		One-half length of ganglion			2						
6	Longitudinal fissure whole length of ganglion. Partial cleavage on	Ventral aspect		2	3		2				
		Dorsal aspect			2						
7	Cleavage of ganglion complete except for slight connection of ganglionic tissue on	Ventral aspect		1	2			1			
		Dorsal aspect		1			2				
8	Total number ganglia examined		31	42	59	56	52	41	45	34	7
9	Per cent showing incomplete separation ganglionic tissue			9.5	23.7	14.3	17.3	2.4			

there seemed to be three lobes. About one-fourth of the ganglionic mass was partially constricted off at both ends and on both aspects. The remaining three-fourths of the ganglionic mass really constituted one lobe, although there was a broad cleft extending up into it for one-third of its length from the peripheral end.

The percentages of the different degrees of cleavage of the ganglia are given in the accompanying table 3.

In figs. 2, 3 and 4 are shown some of the ordinary types of incompletely divided ganglia. These are classified in table 2 under types *4*, *5*, *6* and *7*. As a rule where there was a tendency to septum formation, dividing the ganglion longitudinally, (figs. 3 and 4) this occurred on the ventral aspect of the ganglion. There were 40 instances in which there was some degree of ventral invagination of this character and 16 cases of invagination of the dorsal aspect. In 8 of the cases cited the invagination or septum formation occurred on both the ventral and dorsal aspects at the same time in the same ganglion, so that these 8 are included in both the 40 and 16 cases mentioned above. This leaves then 32 instances of septum formation from the ventral alone to compare with 8 instances from the dorsal alone, or a ratio of 4 to 1.

In the cases where there was a partial splitting of the ganglion at either end, as shown in fig. 2, it occurred more frequently at the peripheral end. Of all the ganglia examined there were 42 that showed a division at the peripheral end and 17 that were divided at the central end. If we deduct the ganglia that are counted in this twice, there are left 29 cases of division at the peripheral end and 4 cases of division at the central end or about 7 to 1, which shows that the division at the central end is relatively infrequent.

The ganglia in which there was a complete division of ganglionic tissue are listed in the accompanying table 4. It will be seen that in a few instances the separation of the ganglionic tissue was complete except for a slight fibrous connection at the proximal end. Here there was a decussation of a few nerve fibres caused by the passage of centripetal sensory axones from one division of the ganglion into the opposite dorsal root fasciculus.

TABLE 3

Percentages of singularity or duplicity

	REGION AND LEVEL FROM WHICH TAKEN	L. 1	L. 2	L. 3	L. 4	L. 5	S. 1	S. 2	S. 3	S. 4
1	Per cent single without modification	90.3	69.1	40.7	42.9	48.1	90.3	93.3	100	100
2	Per cent single with modification	6.5	9.5	15.3	19.6	15.4	2.4	4.5		
3	Per cent incomplete separation		9.5	23.7	14.3	17.3	2.4			
4	Per cent complete division	3.2	11.9	20.3	23.2	19.2	4.9	2.2		
5	Total per cent incomplete or complete division	3.2	21.4	44.	37.5	36.5	7.3	2.2		

TABLE 4

Complete division of ganglionic tissue

	REGION AND LEVEL FROM WHICH TAKEN	L. 1	L. 2	L. 3	L. 4	L. 5	S. 1	S. 2	S. 3	S. 4
1	Complete separation of ganglionic tissue, but slight connection of nerve fibres at — Central end			2	4	5				
	Peripheral end									
2	Complete separation into two ganglionic masses	1	4	10	7	5	2	1		
3	Three lobes present. Complete separation between two of them		1		2					
4	Total number complete division	1	5	12	13	10	2	1		
5	Total number ganglia examined	31	42	59	56	52	41	45	34	7
6	Per cent complete division	3.2	11.9	20.3	23.2	19.2	4.9	2.2		

Three of the ganglia examined had three lobes each. In two of these instances the three lobes were entirely separated from each other. In the other case, two of the three lobes were united by a thin bridge of protoplasmic tissue. The one of these three lobed ganglia from the second lumbar level had a relatively very small oval little mass of ganglionic tissue lying squarely upon and impressing the dorsal aspect of its main mass. One small afferent bundle of nerve fibres entered the peripheral end of the little mass while one small efferent bundle of nerve fibres came away from its central end. The main mass of the ganglion was broader than long. It had upon its dorsal aspect an impression made by the little ganglion lying upon it. Both ends, central and peripheral, contained a deep, broad notch indicative of division. Along the whole length of the ventral aspect a broad, deep furrow extended from notch to notch. Several small afferent bundles of nerve fibres entered at the peripheral end; while at the central end the efferent fibres came away in a number of independent fasciculi grouped into two main bundles, one from either division of the main mass. The ventral root, in this case, as it passed over the central aspect of the ganglion divided into only two divisions. All three lobes of this ganglion lay with their central ends equally distant from the cord.

One of the two triple ganglia from the fourth lumbar level did not have each of its three lobes entirely separated from the other two. The smallest of the three lobes, however, was entirely separated from the other two. This small lobe was elongated, fusiform in shape, and lay along the side of the other two. It had a single afferent bundle of nerve fibres entering its peripheral end, and a single efferent bundle coming away from its central end. The other two lobes of this ganglion had upon their dorsal aspect a bridge of ganglionic tissue connecting them together, the dorsal aspect of the central end of one to the dorsal aspect of the other along its middle. Upon their ventral aspect there was a deep groove, cleft or fissure extending nearly through to the dorsal aspect where it was interrupted by the bridge of ganglionic tissue. Several afferent nerve fibre bundles entered each

of the two connected lobes at their peripheral end. The efferent fibres came away from the central end in two main bundles, one from each of the two united lobes. The triple condition of the ganglion under consideration showed very much better from the ventral aspect than from the dorsal. All three of the lobes had their central ends at slightly different distances from the cord. The motor root divided into three divisions as it passed over the ventral aspect of the ganglion, one of the divisions passing to each of the three groups of afferent nerve fibre bundles.

The other of the two triple ganglia from the fourth lumbar level had each of its three lobes completely separated from the other two. Two of the lobes were of about the same size and shape, both being oval. The third lobe was larger in circumference and longer than either of the other two. Several small afferent bundles entered each of the three lobes at their peripheral end. There were three efferent bundles leaving the ganglion, one from the central end of each of the three lobes. All three of the lobes had their central ends at slightly different distances from the cord. The motor root divided into three divisions corresponding to the three lobes of the ganglion.

The relative position of the two lobes where the ganglion is partly or completely divided is shown in table 5. It will be seen that where there is a complete separation of ganglionic tissue the two divisions of the ganglion are frequently unequally distant from the spinal cord, and in a few instances one of the divisions was found lying entirely beyond the peripheral end of the other. Where there was an incomplete separation of the ganglionic tissue the two divisions were situated in the majority of the cases equally distant from the cord. In both partially and completely divided ganglia the two divisions were of unequal size more often than not. Combining the complete and incomplete separation there were 47 ganglia in which the divisions were of unequal size, as against 30 in which they were of equal size.

TABLE 5

Position and size of the two lobes relative to each other

	REGION AND LEVEL FROM WHICH TAKEN		L. 1	L. 2	L. 3	L. 4	L. 5	S. 1	S. 2	S. 3	S. 4	TOTAL
1	Two divisions of ganglion equally distant from cord	Incomplete separation of ganglionic tissue		3	9	5	4					21
		Complete separation of ganglionic tissue			4	5	6	1				16
2	Two divisions of ganglion unequally distant from cord	Incomplete separation of ganglionic tissue		1	5	3	5	1				15
		Complete separation of ganglionic tissue	1	4	8	6	4	1	1			25
3	Second ganglion lying beyond peripheral end of main ganglion			1	1				1			3
4	Two divisions of ganglion of equal size	Incomplete separation of ganglionic tissue			3	4	6					13
		Complete separation of ganglionic tissue		2	5	6	3	1				17
5	Two divisions of ganglion of unequal size	Incomplete separation of ganglionic tissue		4	11	4	3	1				23
		Complete separation of ganglionic tissue	1	2	7	5	7	1	1			24

MICROSCOPICAL EXAMINATION

The accompanying figure (fig. 5) is from a cross section through a typical double ganglion. In preparing this ganglion for a cross section only enough of the surrounding adipose and loose fibrous connective tissue was picked away to prevent a too ragged appearance of the periphery of the preparation. The epineurium of the ventral root and the capsule of the ganglion were left undisturbed. A transverse block of tissue was cut from the central part of the ganglion and its accompanying ventral root. In the figure we see the ganglionic mass completely separated into two divisions of unequal size. One of them, the smaller, is nearly round. The other, the larger, is of an oblong shape. Each has its own fibrous connective tissue capsule. A small space intervenes between the capsules of the two divisions, which is occupied by loose, fibrous connective tissue, a little adipose tissue, and, small vessels. Several small bundles of nerve fibres may be seen in each division. A process of fibrous tissue, extending inward from the capsule of the larger division on one side toward an indentation in the ganglionic tissue and a thickening in the capsule upon the other side, forms a partial or incomplete septum within this portion of the ganglion. The irregular cleft that is seen passing along the line of continuation of this septum is an artefact. Upon the side of the section corresponding to the ventral aspect of the ganglion are two bundles of nerve fibres, the ventral root fibres, cut in cross section. Each bundle has its own epineurium. They are oval in shape lying end to end, and are placed partially opposite the narrow space intervening between the two divisions of the ganglion. A considerable amount of adipose tissue, loose connective tissue and vessels lies between these two divisions of the ventral root and the corresponding division of the ganglion.

The capsule of the ganglion in the cases where the ganglionic tissue was completely separated into two parts, was in some instances completely divided as is shown in fig. 5. In other cases the capsule was divided upon one aspect of the ganglion only. Upon the other aspect of the ganglion where the division

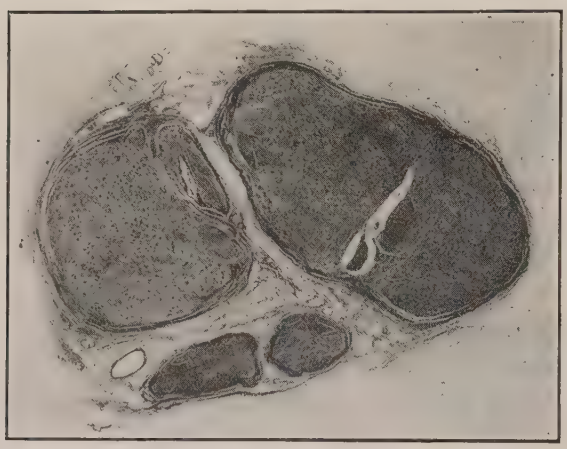

Fig. 5 Cross section of a double third lumbar ganglion, showing complete division into two parts. Note the capsule of either division of the ganglion; the space between the two divisions; the two divisions of the ventral root with their epineurium; the surrounding adipose and loose fibrous connective tissue with blood vessels interspersed; the ganglion cells which appear as black specks a little smaller than pin heads, and the fasciculi of nerve fibres within the two divisions of the ganglion. From a photograph of a 10μ section stained in hematoxylin and eosin. $\times$ 90.

did not occur there was a triangular shaped cleft in the ganglionic tissue which was occupied by a thickening in the capsule from which a process of connective tissue passed inward becoming a septum. This connective tissue septum at a variable distance from its origin split into two processes which diverging as they proceeded onward became continuous with the two arms of the divided capsule entering from the opposite side. The plane of cleavage was in all instances dorso-ventral.

Where the ganglion was not completely separated into two divisions, in some instances there was an invagination of the capsule upon one aspect of the ganglion for a variable distance. In other instances the capsule was continuous across the cleft between the two divisions, passing directly over the plane of cleavage at right angles to it from one lobe of the ganglion to the other. The septum here was a process of connective tissue of varying breadth that passed inward from the capsule toward,

but not to, the opposite aspect of the ganglion. In cases like the one just mentioned of an incomplete septum as well as in the ones where the capsule extended nearly or clear through to the opposite aspect, there occurred along the central region of the septum or of the prolongation of the invaginated capsule a zone of fibrous connective tissue of less density than that upon either side of it, indicating a distinct line of cleavage between the two divisions of the ganglion. On the aspect of the ganglion where the septum would have emerged, if it had been complete, there was a slight indentation in the ganglionic tissue with a corresponding thickening in the connective tissue of the capsule at that point, suggestive of an aborted attempt to give off an inward passing septum, or to form an invagination of the capsule. In cases where the septum or continuation of the invaginating capsule failed to pass clear through, there was noticeable an arrangement of the connective tissue of the ganglion so as to lie in line with the direction of the septum indicating where the cleavage would have occurred had the septum been complete.

It was found that the invagination of the capsule and the inward passage of the septum, where neither resulted in a complete cleavage, started from the ventral aspect much oftener than from the dorsal. I also found that the degree of cleavage had no influence upon the relative size of the lobes; that in point of relative size the tendency was toward an unequal division; and that in many instances, especially so in the complete divisions, the central ends of the two lobes of the double ganglia did not lie in a single plane placed at right angles to the long axis of the ganglion.

In connection with the study of the ganglia the following features were noted regarding the nerve roots belonging to them. In some of the ganglia, particularly in the lumbar and in the upper sacral regions, the motor root at a point central to the central end of the ganglion on the dorsal root divided into two bundles as it passed over the ventral aspect of the aforesaid dorsal root ganglion. The division was a constant occurrence in all cases where the ganglion was relatively broad from side to side; where it was double, or where it showed indications of duplicity. The two divisions of the ventral root, lying side by side at first, diverged

slightly as they approached and passed beyond the peripheral end of the ganglion to join with the dorsal root fibres in the formation of the two primary divisions of the spinal nerves.

As a characteristic of the ventral root, whether occurring as a single nerve bundle, or being divided into two bundles, it very frequently was of an oval cross sectional outline, regardless of whether it was bound down tightly to the ganglion, was placed just within the capsule of the ganglion, or was some slight distance away. As an exception to this oval characteristic the small motor root of the thoracic region showed a greater tendency to roundness than was seen in any of the other regions of the cord. The same oval cross sectional shape or outline held true with even greater constancy for the two divisions of the ventral root where the motor fibres were grouped in two bundles than was the case where this root was undivided.

At the peripheral end of all the larger and of many of the smaller dorsal root ganglia the entering sensory nerve fibres were grouped into a number of bundles of irregular size. In the regions of the cord where the roots and the ganglia are the largest the fibres entering the ganglia from the periphery were arranged in the greatest number of bundles. The division or partial division of the ganglia did not affect this grouping of the entering fibres in the least; for in case the ganglion was double each division then took its proportionate share of the entering bundles.

RESUMÉ

The ventral root, usually oval itself, was frequently divided into two oval bundles in the vicinity of the ganglion. The dorsal root fibres, central to the ganglion, were grouped into one, two or several bundles; while peripherally to the ganglion they were grouped into a number of small bundles. Where division of the ganglion occurred, it was the result of either an invagination of the capsule, or of a septum passing in from the capsule. The degree of division ranged from the ganglion that was single to the one that was triple with three completely separated lobes. Division occurred much oftener at the peripheral end than at the central end.

Among the cervical and the thoracic ganglia that were examined there were none that were double. In the lumbar region and in the upper sacral region there was a marked tendency to occur double, either from an incomplete or from a complete separation of the ganglionic tissue into two divisions. This tendency toward division, whether complete or incomplete, was most marked in the third, the fourth and the fifth lumbar levels occurring here as often as once in every third case; whereas complete division of the ganglia in the same levels occurred once in every fifth case.

In conclusion I wish to acknowledge my indebtedness to Prof. Novy for the preparation of the photograph which is reproduced in fig. 5, and I wish also to take this opportunity to thank Professor Streeter, without whose advice and stimulus this study would not have been completed.

THE RETICULUM OF LYMPHATIC GLANDS

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TEN FIGURES

The silver impregnation method of Bielschowsky[1] in its newest form has with some modifications been applied to the study of tissues other than those of the nervous system for the staining of whose neurofibrils it was originally devised. Maresh[2] and Studnicka[3] seem to have been the first to appreciate its wider applicability. Levi[4] slightly modified the method for use with connective tissues, and his publication stimulated various Italian observers to a study of the collaginous and reticular tissues in a considerable variety of organs. Ciaccio, Cesa-Bianchi, Alagna, Balabio, Favaro, and others have put forward such publications, and the method has been shown to serve as a fairly distinctive stain for the peculiar fibres of reticular tissue. This method applied to nature tissues blackens only the reticular tissue and shows beautifully its distribution.

The inequality in the distribution of the lymphocytes in lymphatic glands with formation of denser areas is well known. The areas of great density are: 1, the cortex as compared with the medulla; 2, the follicles; 3, the cords. The increased density of the cortex is not solely due to the presence of follicles within it, for the intervening areas are of greater density than much of the medulla. In the follicles the periphery is of greater density than the central portion. This is due to the presence of the

[1]Bielschowsky and Pollack, Neurol. Centralbl., 1904, Bd. 23, 387.
[2]Centralbl, f. allg. Path., 1905, Bd. 16, 641.
[3]Studnicka, F. K, Zeitschr. f. wis. Mik., 1906, Bd. 23, 414.
[4]Levi, G., Monitore Zool. Ital., 1907, Anno. 18, 290.

germinal centers of Flemming. In the medulla the leucocytes in the cords are densely packed as compared with those in the intervening sinuses. While the facts regarding the crowding of leucocytes have been generally recognized, the somewhat similar distribution of the reticulum has not been so frequently observed. Silver blackened sections of lymphatic glands show that the reticulum, like the lymphocytes, is crowded at certain points. The denser areas are found in the cortex, the medullary cords, at the periphery of the follicles, and about the blood-vessels and trabecula. The condensation of reticulum beneath the capsule on the borders of the peripheral sinus, and at the boundary line between the cords and trabecula on the one hand and the cortical and medullary sinuses on the other, is so pronounced as to form a distinct membrane. Of two comparable areas it often happens that the denser the lymphoid cells the denser the reticulum. Thus, the reticulum of the cortex is denser than that of the medulla, that at the periphery of a follicle is denser than in its center, that of the medullary cords is coarser and often denser than that of the sinuses: of course so general a rule is not without exceptions, notably in that the cortical tissue between the follicles is frequently provided with a very dense and firm reticulum.

Ciaccio[5] has already called attention to the increased density of the reticulum in the periphery of the follicle as compared with the broad meshes and scant fibres of the germinal centers. This perifollicular plexus of Ciaccio is very characteristic. It consists of course fibres arranged to form peculiar lozenged-shape meshes. Ciaccio states that in the active follicles of the spleen and lymphatic glands the intrafollicular network is rare, while in the inactive it is nearly as dense as the perifollicular plexus. One must however call attention to the possible error resulting from the examination of sections whose planes pass through only the peripheral portions of certain follicles (fig. 2). In such cases the apparently active follicles show a dense network throughout a considerable portion of their diameter but this net is obviously

[5]Anat. Anz., 1907, Bd. 31, 594.

All figures, unless otherwise stated, were drawn with the aid of the Edinger projection apparatus and the magnification accurately measured. All sections from which figures were made had been stained by the method of Bielschowsky.

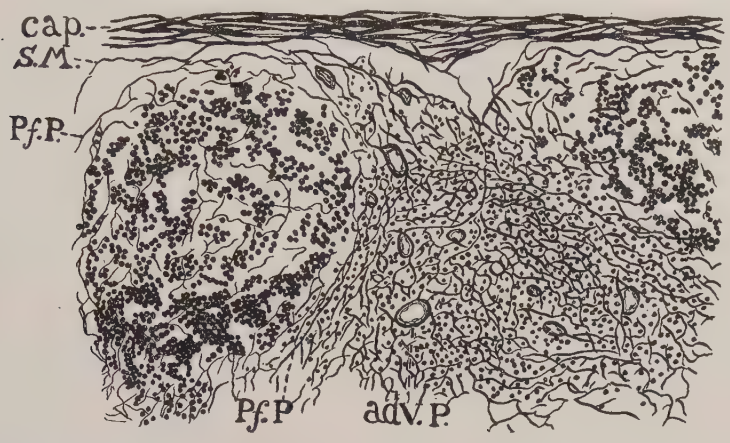

Fig. 1 Follicles at the periphery of a lymphatic gland of a dog. *Avd. P.*, adventitial plexus; *Pf.P.*, perifollicular plexus; *S. M.*, subcapsular membranes. × 200, reduced ¼ in reproduction.

Fig. 2 Two adjacent follicles in the cortex of a lymphatic gland of man. The section passes only through the surface of the follicles and apparently shows a dense intrafollicular plexus which is, however, in reality a surface view of the perifollicular plexus. The coarseness and density of the plexus is apparent on comparison with the intrafollicular plexus shown in fig. 1. × 256, reduced ¼ in reproduction.

that of the peripheral plexus, the germinal center lying outside the plane of the section. This is clearly shown in many of my sections both in the lymphatic glands and in the intestine, spleen and other lymphoid organs. The intrafollicular plexus of a lymphatic nodule rarely approaches the density of the perifollicular, and some of those whose intrafollicular plexus showed the closest net have been follicles which in axial section showed a very distinct germinal center of Flemming.

Ciaccio (loc. cit.) has also called attention to the perivascular adventitial plexus of reticulum occurring in lymphoid organs. I can corroborate his observations in so far as I find that such an adventitial plexus surrounds all of the vessels within the lymphatic gland (figs. 1, 6 and 7). I desire to call attention, however, to two other plexuses which have not hitherto been described as formed by the reticular fibres. These plexuses are often so dense as to form reticular membranes; they are found, the one, pericordal, limiting the surface of the medullary cords and so forming a wall for the lymphatic sinuses of the medulla, and the other a double membrane, the subcapsular, at the surface of the gland beneath the capsule where it forms limiting walls for the peripheral lymphatic sinuses.

A closer examination of the peripheral sinuses shows that throughout a considerable portion of their extent they lie between two distinct membranes of pure reticulum against which the endothelium is applied. The outer subcapsular membrane (*O.S.M.*, fig. 3) is in contact with the capsule and its fibres to some extent intertwine with the innermost collaginous fibres of the capsule. Here and there, especially where it passes from the surface of the capsule to the trabecula, the outer subcapsular membrane may be partially detached from the collaginous tissue upon which it elsewhere lies. At each trabeculum its fibres are continued into the interior as well as upon the surface of the fibrous septum, so that the trabecula contain throughout a considerable proportion of reticulum, whereas in the capsule this tissue is confined to the innermost layer of the membrane.

The inner of the two subcapsular reticular membranes is formed by a condensation of the reticular network of the cortex of the

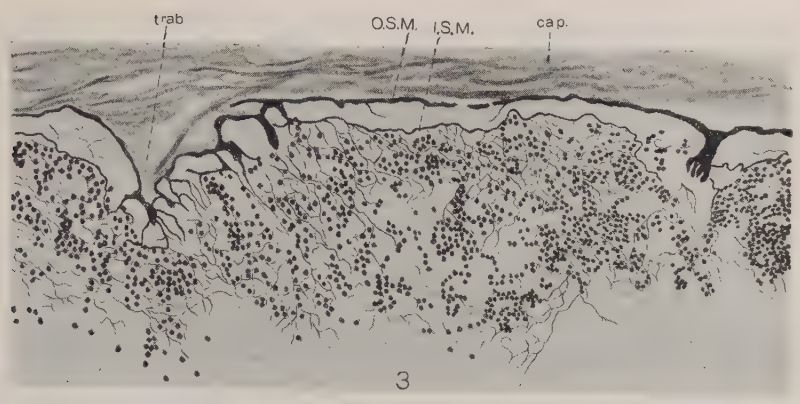

Fig. 3 The peripheral sinus and its reticular subcapsular membranes from a lymphatic gland of a dog. *Cap.*, capsule of the gland; *I.S.M.*, inner subcapsular membrane; *O.S.M.*, outer subcapsular membrane; trab., trabeculum. × 229, reduced $\frac{2}{5}$ in reproduction.

organ, and since it represents a condensation only, it is as one must expect, much more evident at some points than at others. Here and there it forms an almost continuous line along the cortical surface of the organ (*I.S.M.*, fig. 3) while elsewhere one may find areas where the condensation of reticulum is so slight that in transections a membrane can scarcely be discerned.

In the peripheral sinuses, between the two reticular membranes, the reticulum forms a loose network of delicate fibres and very broad meshes. The fibres of this net become directly continuous with those of the reticular membranes.

In the medulla a reticular membrane occurs on the surface of each of the cords, where it forms a limiting wall for the medullary lymph sinuses. Certain lympho-glandulae in which the cords are numerous and characteristic show continuous lines of reticular membranes on the surface of each cord (fig. 4). Here and there the inner subcapsular membrane may be reflected inward along the trabecula to become continuous with the pericordal membranes (fig. 5B) so that the peripheral sinus passes directly into the medullary. But more frequently the inner subcapsular membrane is lost in the cortical reticulum in the vicinity of the trabecula, the fibres of the outer wall of the sinus pass into the

Fig. 4 Photomicrograph of two medullary cords of a dog's lymphatic gland; each is bounded by a distinct pericordal membrane. The small blood-vessels within the cord show well the adventitial plexus. × 250,reduced $\frac{1}{5}$ in reproduction.

trabecula and within the gland become frayed out, as it were, the fibres being continuous with those of the cortical reticulum: in this case the peripheral sinus directs its flow of lymph into the dense cortex, through which lymph must percolate in order to reach the medullary lymph sinuses.

A third series of reticular membranes is formed about the walls of the blood vessels by the adventitial plexuses of Ciaccio, and similar adventitial or peritrabecular plexuses (pericordonal plexus of Balabio) about the nonvascular as well as the vascular portions

of the trabeculae. In the vascular trabecula of the lymphatic glands this plexus forms no part of the wall of artery or vein but lies in the substance and upon the surface of the fibrous trabeculum, the fibres of the plexus being continuous with those

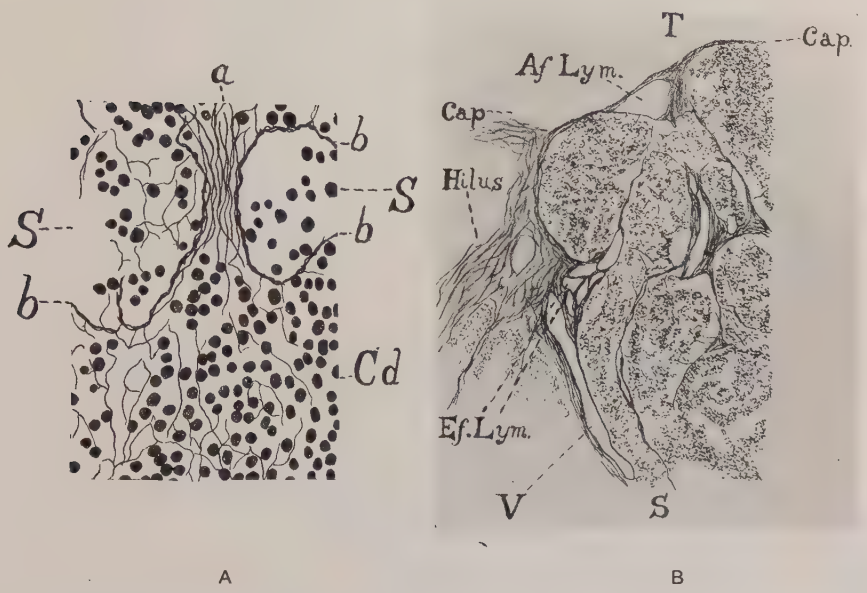

Fig. 5 Two views of the pericordal plexus. A, surface view. At the point *a*, the pericordal plexus is seen in tangential section and shows its membraneous character; at the points *b*, the same membrane or plexus has been cut in transection. *Cd.*, medullary cord; *S*, medullary sinus. From a lymphatic gland of a dog. × 400, reduced ¼ in reproduction.

B, a portion of the cortex of a lymphatic gland of man, near the hilus. The medullary sinus, *S*, leads directly from the subcapsular sinus about the trabeculum, *T*, to the medulla of the gland. *Af. Lym.*, afferent lymphatic; *Ef. Lym.*, efferent lymphatics; *Cap.* capsule of the gland; *V*, vein, making its exit through the connective tissue of the hilus. The sinuses are bounded by the pericordal plexus. × 60, reduced ¼ in reproduction.

of the trabeculum. This is well shown in fig. 6, in which the collaginous adventitia of the artery and of the lymphatic vessels is seen well within the blackened trabecular reticulum.

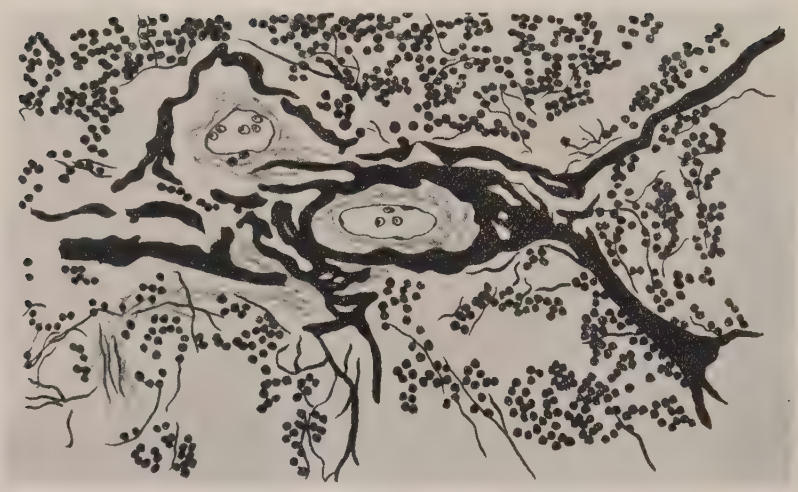

Fig. 6 The adventitial plexus about the arteries in a vascular trabeculum in the medulla of a lymphatic gland of man. The plexus lies just outside of the tunica adventitia. × 220, reduced ¼ in reproduction.

Balabio[6] states (p. 137) that the adventitial plexus of the blood vessels has not the importance in the lymphatic glands that it has in the spleen. I can verify this statement so far as it concerns the arteries, the periarterial plexus in the spleen being much heavier than in the lymphoglandulae; but the same is scarcely true of the veins (fig. 7). The small venules which Calvert[7] has described at the periphery of the follicles (figs. 1 and 8)stand out prominently in the lymphatic glands because of their coarse, close-meshed, adventitial plexus. With the exception of those vessels lying within the vascular trabecula I find the thin-walled veins of the spleen very deficient in those adventitial fibres which blacken with silver.

Ciaccio (loc. cit.) dismisses the lymphatic capillaries with the statement that they have a structure similar to that of the blood capillaries. On p. 600 he says: "I capillari linfatici presentano

[6]Anat. Anz., 1908, Bd. 33, 135.

[7]Calvert, W. J., Anat. Anz., 1897, Bd. 13, 174; and Johns Hop. Hosp. Bull., 1901, vol. 12, p. 177.

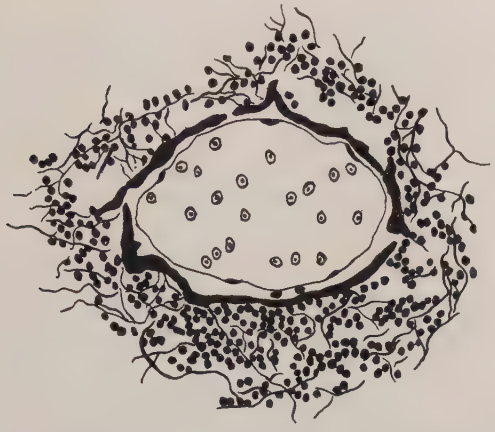

Fig. 7 Periadventitial plexus about the wall of a medullary vein in a lymphatic gland of man. × 255.

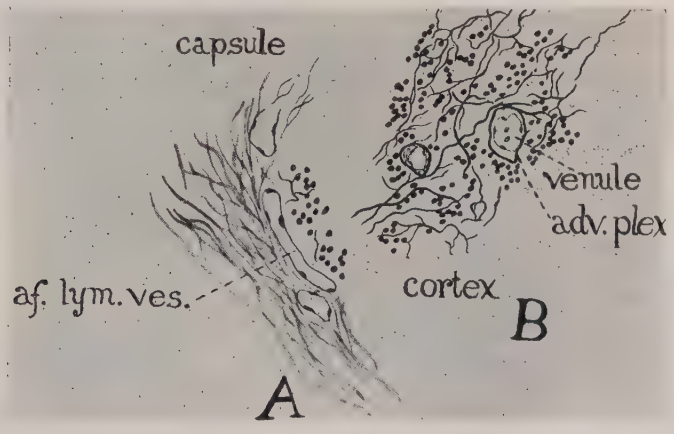

Fig. 8 Lymphatics and venules from the capsule and cortex, respectively, of a lymphatic gland of a dog. *A*, afferent lymphatic vessels in the capsule; *B*, venules in the adjacent cortex of the same section; *adv. plex.*, adventitial plexus; *af. lym. ves.*, afferent lymphatic vessel. × 225.

quasi la stessa struttura dei capillari sanguigni, differendo da questi soltanto per la forma, larghezza e disposizione." From my observations of the lymphatic vessels I am led to believe, however, that the volume of reticulum in the adventitial plexus is considerably less in the lymphatics than in veins of correspond-

ing size. This is specially well shown if one compares vessels somewhat larger than capillaries, *e.g.* the venules at the periphery of the follicles and the afferent lymphatics in the capsule, (fig. 8), or such intratrabecular lymphatics as are shown in fig. 5B.

Within the mass of lymphocytes which forms the parenchyma of the organ the reticulum is everywhere found. At the periphery in the cortex and within the cords of the medulla the network is formed by course fibres with polygonal meshes of relatively small diameter Within the sinuses of both cortex and medulla the fibres are much finer and the polygonal meshes broader so

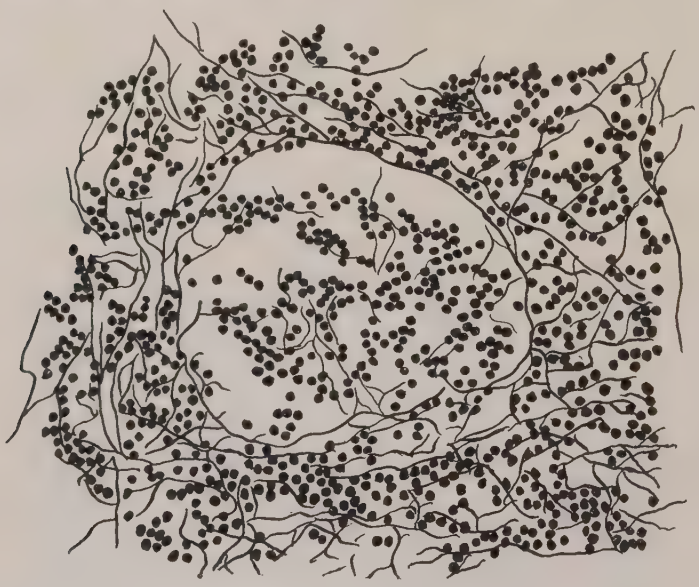

Fig. 9 A medullary sinus in transection, showing its very delicate network of reticular tissue. From a lymphatic gland of man. × 255.

that in the sinuses the total volume of reticulum must be only a small fraction of that in the denser portions of the gland.

The broadest mesh is that in the germinal centers of follicles, the finest fibres those of the sinuses. The shape of the mesh is typically lozenge-shaped in the perifollicular plexus of Ciaccio, and polygonal elsewhere, though here and there the polygonal spaces are considerably elongated in the directions of stress or of lymph

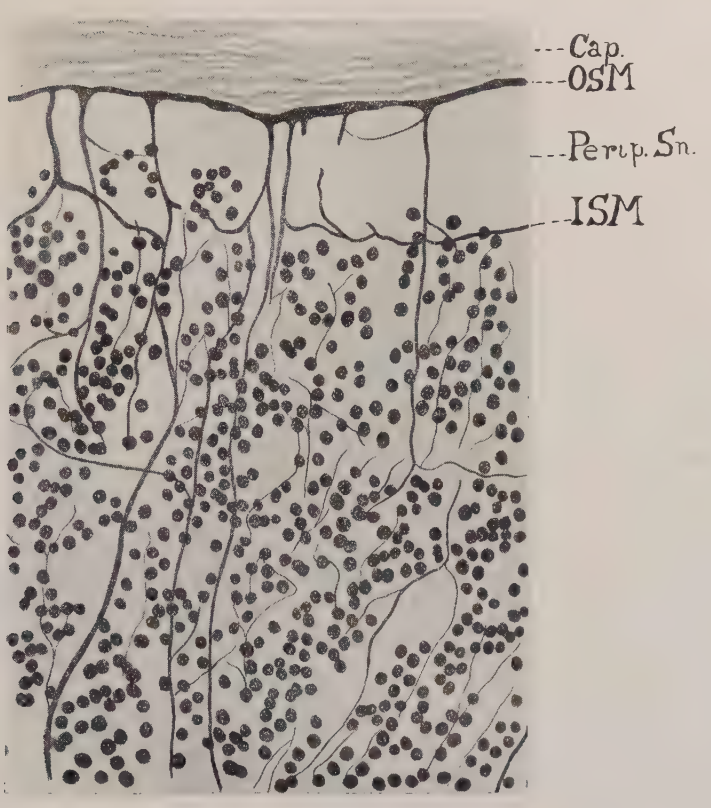

Fig. 10 The reticulum at the periphery of a lymphatic gland of man; the meshes are elongated in a direction perpendicular to the capsule. *Cap.*, capsule of the gland; *ISM*, inner subcapsular membrane; *OSM*, outer subcapsular membrane; *Perip. Sn.*, peripheral sinus. × 625, reduced $\frac{1}{3}$ in reproduction. Camera lucida.

flow; this is most noticeable at the periphery of the cortex where beneath the subcapsular membranes the meshes are elongated in a direction perpendicular to the surface (fig. 10). This arrangement is confined to the intervals between the cortical follicles for wherever the surface of a follicle comes into contact with the inner subcapsular membrane of the peripheral sinus the meshes of the perifollicular plexus appear to be flattened against the reticular membrane and the network of reticulum thus rendered more dense than elsewhere.

SUMMARY

The lymphatic glands are everywhere pervaded by a reticulum which blackens with silver impregnation by the method of Bielschowsky. This reticulum is condensed to form more or less complete reticular membranes bounding both cortical and medullary sinuses. Hence one finds these dense plexuses or reticular membranes in several locations, viz., *subcapsular* (inner and outer wall of the peripheral lymphatic sinus), *pericordal* about the medullary cords, *peritrabecular* (equivalent to the 'pericordonal' of Balabio) and *adventitial* (where they surround the small naked blood-vessels).

The reticulum forms a net of close meshes in the periphery of the follicles (perifollicular plexus of Ciaccio), in the cords a cordal plexus, and in the peripheral portion of the cortex a cortical plexus. The meshes are broad in the subcortical zone, still broader in the cortical and medullary sinuses, and broadest in the germinal centers of active follicles. The form of the mesh is lozenge-shaped in the perifollicular plexus, sometimes elongated in the cortical plexus, and elsewhere polygonal.

The reticulum is everywhere a continuous mass of stroma, the fibres of both reticular membranes and plexuses being continuous with each other throughout the gland.

THE DEVELOPMENT OF THE LYMPHATIC SYSTEM IN THE REPTILES[1]

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The recent completion of an extensive series of investigations on the development of the lymphatic system in the mammalian embryo has cleared the way for the study of the same structures, both in their ontogeny and in their adult condition, in other vertebrate classes. Work on these lines has been in progress in this laboratory during the past year, and certain of the results were presented at the twenty-seventh session of the American Association of Anatomists at the Ithaca meeting in December 1910.[2] The purpose of these communications was to show that in the sauropsid amniotes the identical genetic ground plan of lymphatic development and adult organization obtains which, by the previous researches referred to, has been demonstrated for the mammalia. The antecedent work on mammalian lymphatic ontogeny, thus forming the basis for comparison with avian and reptilian conditions, has been carried on partly in collaboration with Prof. C. F. W. McClure of Princeton University and partly independently in the anatomical laboratory of Columbia University. Inasmuch as these researches will of necessity be referred to in comparing the conditions found in the sauropsid amniotes with those obtaining in the mammal, I append a list of the publications containing the results arranged chronologically in the order of their appearance. (Literature Cited). In this communication I shall offer a brief résumé of the

[1] Read at the 27th meeting of the Association of American Anatomists, Cornell University, Ithaca, N. Y., December 27–31, 1910.

[2] At the same meeting my associate, Mr. A. W. Miller, described the development of the anterior or jugular lymphsac in the chick.

THE ANATOMICAL RECORD, VOL. 5, NO. 6
JUNE, 1911

main results obtained in a study of the development of the lymphatic system of certain reptilian embryos. The findings here given are based on the study of serial sections of the following reptilian embryos and on plastic reconstructions of a number of the more important stages.

LIST OF MATERIAL EXAMINED AND IN PART RECONSTRUCTED:

	MILLIMETERS	SERIES
Aspidonectes spinifer	5	207
	6	300
	7	208
	7.5	301
	8	209
	8.5	313
	11.5	309
	13.5	310
Chelydra serpentina	8	353
	8	359
	8.5	354
	10	350
	10	358
	15	317
	15.5	319
Chrysemys marginata	12	322
	14.5	321
Chrysemys picta	10	308
	10	311
Pseudemys scripta	7	312
Turtles not identified	4	305
	4.5	304
	4.5	316
	5	303
	6	302
Cnemidophorus sexlineatus	7.5	352
Sceloporus undulatus	4	161
	4.5	329
	5	307
	5	331
	5.5	330
	6	314
	6.5	306
	7	323
	7	324
	7	334
	7	347
	7.5	145
	7.5	327
	7.5	328
	7.5	346
	8	332
	8	342
	8	348
	8.5	349
	9	156
	9	157
	9	333
	9	341
	9	343
	10	344
	11	162
	11	345
	12	298
	14	299

The measurements given are only approximate indications of the stages, as the differences in curvature of the entire embryo,

particularly the lizards, and the length and varying position of the tail make accurate determination of the true total length impossible. We have tentatively tried to use the greatest sagittal head measure as a guide in grouping the individual series chronologically, but this procedure also has defects. For the present it seems therefore preferable to consider the material as divided into successive stages as determined by the condition of vascular development, independent of the actual measure, which, as stated, has only an approximate value in classifying the individual series.

The following are the main results obtained in the investigation:

1. The reptilian embryo develops not only the caudal or posterior lymphatico-venous heart, which is carried into the adult organization, as a typical vascular character of the entire class, but a reduced anterior or cervical structure of the same significance develops as the *jugular lymphsac.*

2. The reptilian jugular lymphsac develops along genetic lines which, in their broad bearing on the general problem of vertebrate lymphatic ontogeny, are identical with those determined in detail by McClure and myself (2, 7) in embryos of the cat.

The reptilian jugular lymphsac arises by confluence of venous elements detached from the permanent venous channels of the precardinal area. It then evacuates its early blood contents, separates temporarily from the haemal vascular system, establishes secondary connections with the systemic lymphatic vessels of the anterior part of the body and of the anterior extremity, and finally reenters the venous system at a definite and constant point of secondary lymphatico-venous junction.

3. The *systemic lymphatic channels,* in contradistinction to the *jugular sacs* of venous derivation, arise *independently* of the haemal vascular system by confluence of mesenchymal spaces.

4. These independently formed systemic lymphatics, which reach in the reptile an enormous degree of development, are formed by the successive union of mesenchymal tissue spaces, are *not derived from veins,* and become lined with a *lymphatic vascular endothelium, not derived from or connected with a preexisting haemal vascular endothelium.*

5. These independently developed systemic lymphatic channels and sinuses subsequently establish two sets of secondary connections in the region under consideration:

a. with the jugular lymphsac, in a district corresponding to the cephalic division of the ventral mammalian sac.

b. with the venous system, through the intervention of a rudimentary jugular lymph heart, which belongs to the morphological area of the mammalian jugular lymphsac (caudal division of ventral portion), but which in the Reptile develops as a distinct structure for the purpose of affording the link eventually joining the independently developed systemic lymphatic channels and the definite functional veins.

The reptilian lymphatic ontogeny repeats, therefore, in all of the main lines, the developmental history of the homologous mammalian structures as established by the preceding investigations above quoted. The reptile completely agrees with the mammal in exhibiting genetically the development of the final and definite lymphatic system as the product of the union of two components of different origin, and of vastly different extent:

A. The extensive channels and sinuses of the systemic lymphatic apparatus, developed independently of the veins, by confluence of mesodermal intercellular spaces.

B. The jugular or reduced anterior cervical lymph hearts, derived directly from the veins, and serving, through secondary connections, as portals of entry of the anterior systemic lymphatic channels into the definite venous system.

Thus the reptile measures up in every particular to the postulates of the theory of vertebrate lymphatic development previously determined (3, 4, 6) on the basis of the embryological investigation of the mammal, and the two amniote classes appear perfectly in accord and consistent in their main lines of general lymphatic development. It is rather surprising to find this congruence of developmental conditions carried through as perfectly as will be shown in the detailed publication to follow, and the comparative vascular organization affords strong evidence for the close phylogenetic association of reptilian and mammalian structure.

With general agreement of the basic developmental principles governing lymphatic and haemal ontogeny in these two amniote classes, the reptilian embryo shows certain minor and secondary differences, when contrasted in detail with the mammal. These differences are structural expressions of the *adaptation* of the common genetic ground plan of development to the specialized physical and metabolic conditions distinguishing the two classes. They carry the same significance as, for example, pertains to the divergence observed in comparing the development of the reptilian arterial arches, and the resulting adult organization of this section of the vascular system. They do not alter the uniform and consistent character of the genetic groundplan common to both classes. On the other hand, their careful determination and close critical comparison with the corresponding mammalian ontogenetic processes is of very real interest. They offer, in the first place, most important and conclusive confirmatory evidence of the validity of the genetic interpretation of mammalian lymphatic development previously propounded (1, 3, 4, 6, 7, 8, 9, 10, 11). Then again, the reptilian embryo explains in a most clear and satisfactory manner certain conditions established by direct and repeated observations in the mammal, which heretofore appeared difficult of interpretation in their structural and functional significance, and which could only be recorded as established ontogenetic facts, without affording, in their own genesis, the clue to the reason for their development.

Thus, for example, the temporary separation, after evacuation, of the mammalian jugular lymphsacs from the veins and their subsequent secondary reunion with the same at definite points, was observed and recorded by McClure and myself uniformly in the proper stages in our study of the cat embryo (cf. loc. cit. 7, p. 289), but could not be accounted for on morphological or physiological grounds. The ontogeny of the homologous structures in the reptilian embryo shows clearly that this puzzling process is due to the influence of the extensive temporary subcutaneous lymphatic drainage along the lateral line area in the younger stages.

It is therefore necessary, as in the case of the mammal, to consider the ontogenetic history of the entire reptilian lymphatic apparatus under the following three headings:

1. Structure and development of the lymphatico-venous hearts.
2. Structure and development of the independently formed systemic lymphatic channels.
3. Union of these two genetically different components and the establishment of the final and definite adult lymphatico-venous connections.

The present communication is confined to a brief summary of these conditions in the anterior region of the embryo, for the purpose of establishing a basis for comparison with the definitely ascertained mammalian type of development.

1. DEVELOPMENT IN THE REPTILIAN EMBRYO OF THE ANTERIOR OR CERVICAL LYMPH-HEART RUDIMENTS HOMOLOGOUS WITH THE JUGULAR LYMPHSACS OF THE MAMMAL

The area of the adjacent segments of the pre- and postcardinal veins, including their confluence at the Cuvierian junction, which in the mammalian embryo furnishes the finally continuous and confluent anlages of the jugular lymphsac, is, in the reptilian embryo, separated into two distinct districts, which can be directly homologized with what McClure and I defined, in our developmental analysis of the jugular lymphsacs of the cat (7), as the *ventral* and *dorsal veno-lymphatic plexuses*, of which the former presents in the earlier stages a distinct separation into a *cephalic* and a *caudal division*. We based our interpretation of the definite typical double lymphatico-venous tap, at the common jugular and jugulo-subclavian venous angles respectively, and the explanation of the adult variants, caused by uni- or bilateral default of one or the other of these genetically possible communications, on this basic organization of two primarily distinct divisions of the jugular lymphsac. Subsequently McClure and Silvester demonstrated the consistent adult adaptations of this common genetic groundplan of lymphatico-venous connections in a large and representative series of mammalian forms (5), and thus proved the

uniform type prevalent in mammalia in this segment of vascular organization.

The reptilian embryo presents the same type of development in the jugular lymphsac area, but owing to the large size and distinct character of the components entering into the formation of the sac, its genesis, compared with the involved and complicated mammalian conditions, is almost reduced to a schematic demonstration of the latter. The ventral veno-lymphatic element is divided into a distinct cephalic and caudal portion, both clearly separated, up to their final organization and ultimate secondary union with each other, from the dorsal sinus. The correspondence with the ascertained genetic processes of the mammalian embryo and the strict homology of the individual veno-lymphatic components of the jugular lymph sac in the two classes is truly remarkable. But, as above stated, the reptilian organization is built on broad and easily determined lines, with simple and well defined individual elements, in strong contrast to the multiple minute plexiform veno-lymphatic components which form the genetic basis for the development of the mammalian jugular lymph sac.

The reptile differs from the mammal in two respects:

1. As far as up to now definitely ascertained (in lacertilian and chelonian embryos) the final and permanent connections of the jugular lymphsac with the veins is established in a single tap, involving the caudal division of the ventral sinus and the correlated segment of the precardinal vein. In establishing this connection a modification of the mammalian type is encountered which will be subsequently described in detail with the aid of adequate illustrations. In the material heretofore examined this single tap replaces the typical double secondary lymphatico-venous union of the mammal.

2. In both the cephalic and caudal divisions of the ventral sinus, the reptilian embryo develops, in association with the vascular channels, a temporary striped musculature which on the one hand harks back to earlier phylogenetic stages of complete lymphatico-venous heart development, while on the other hand it removes the last possible doubt as to the actual homology of the

higher (avian and mammalian) jugular lymphsacs with a member, or a consolidated group of successive segmental members, of the series of lymph-hearts encountered in the anamnia. Hence the description of the equivalent of the mammalian jugular lymphsac in the reptilian embryo calls for the consideration of the three separate and distinct areas above outlined.

The detailed analysis of the latter furnished by McClure and myself for the mammal in the full publication quoted (7) makes it possible to draw a direct comparison between the individual components entering into the formation of the jugular lymph sacs in mammals and reptiles respectively, and to indicate the homologies by employing the color scheme adopted in the figures accompanying the mammalian account.

A. Anterior or cephalic division of the ventral veno-lymphatic sinus (corresponding to area indicated by the red color in the figures of the mammalian sac)

In the proper reptilian stages the cephalic arch of the precardinal (v. cephalica lateralis) extends caudad into the straight segment to a point of union with a large medial trunk, which, in a ventro-dorsal direction drains the surface of the neural tube and becomes, as vena orbitalis primitiva, closely associated with the optic vesicle and orbital area. This vein begins as an expanded orbital sinus, which narrows, in descending caudo-laterad, to its angular confluence with the straight segment of the precardinal. The latter channel, in the earlier stages, is surrounded by a capillary venous plexus, and receives the terminals of a number of dorsal tributary radicles. Subsequently these perivenous vascular elements become detached from the main channel and coalesce into a multilocular veno-lymphatic sac, which finally separates completely from the main venous trunks from which it arose. The resulting sac is homologous with the jugular lymphsac of the mammal (cephalic division of ventral sinus) and develops in exactly the same manner by confluence of originally discrete veno-lymphatic components.

In some of the earlier reptilian stages, expecially in chelonian embryos, the separation of the dorso-medial somatic from the

dorso-lateral veno-lymphatic components of the precardinal tributary system appears as clearly marked as in the mammalian embryo. Typical dorso-medial lines of somatic venous drainage into the main precardinal channel are absolutely differentiated from the more plexiform group of dorso-lateral channels, constituting the anlages of the future jugular lymph sac, and, in this stage, still in open and multiple connection with the main venous trunk of the precardinal.

The main precardinal vein, during the process of formation of this jugular veno-lymphatic sac and its subsequent detachment from the functional venous channels, develops, at and adjacent to the angle of confluence with the orbital vein, an enlarged segment, with diverticular extension of the lumen and distinct production of an enveloping striped musculature, which in every respect corresponds to a rudimentary veno-lymphatic heart.

When this stage has been attained the multilocular jugular sac is separated from the veins, but still closely related to the same. The precardinal vein has interposed in its course the enlarged area, surrounded by a muscular envelope, above described as a typical early lymphatico-venous heart, and the orbital vein opens into the precardinal at this point. In the succeeding stage the orbital vein becomes entirely detached at its point of confluence with the precardinal and remains then for a time as a closed venous sac, beginning in the orbit by a widely expanded portion, and terminating, in a pointed extremity, at the lymph-heart area of the precardinal. This elongated sac lies on the ventro-medial aspect of the jugular lymphsac, which in the meanwhile has extended so as to partially surround and embed it, and finally becomes completely incorporated in the same. As a matter of fact, it constitutes its main component, the portion contributed by the perivenous veno-lymphatic plexus being relatively insignificant. Compared with the mammalian conditions, as determined by McClure and myself (7), the general area of development of this segment of the reptilian jugular lymphsac corresponds to the elements colored red in the figures of the reconstructions of mammalian embryo accompanying the publication quoted.

B. Posterior or caudal division of ventral veno-lymphatic sinus (corresponding to the area indicated by the blue color in the figures of the mammalian sac)

This element is formed entirely by a large venous sac which lies ventro-lateral to the main precardinal vein and in the early stages drains cephalo-caudad into the latter. It subsequently evacuates its blood contents and becomes detached from the functional venous channels, forming the caudal division of the ventral sinus. I believe it to be strictly homologous with what McClure and I described in the ontogeny of the mammalian jugular lymph sac as "*precardinal tributary 4 and the associated para-precardinal channel*" (loc. cit. 7, pp. 211–216). It represents, generally speaking, the area of lymph sac formation, which in the publication just quoted, is indicated by the blue color in the figures accompanying both the general developmental analysis of the mammalian jugular lymph sac and the description of the individual embryos there given in detail.

It subsequently shares the fate of its mammalian homologue, being incorporated with the cephalic division and with the dorsal veno-lymphatic plexus into the single jugular lymph sac of the later stages.

C. Dorsal division of the veno-lymphatic plexus (corresponding to the area indicated by the yellow color in the figures of the mammalian sac)

This element forms in the reptilian embryo a relatively small part of the bulk of the entire jugular lymph sac, but is distinguished by the length of the derivative which accompanies the lateral line vein and corresponds to what McClure and I described as the "primitive ulnar veno-lymphatic" in the mammalian embryo.

In the earlier and purely venous stages of the reptilian embryo the lateral vein of the body wall unites with the precardinal to form the primitive Duct of Cuvier, before the definite establishment of the postcardinal venous line, and in this agrees with early mammalian embryos. (cf. loc. cit. 7, figs. 25 and 26.)

The dorsal division of the veno-lymphatic sinus is, both in its somatic and anterior limb-bud portions, a derivative of this early venous plexus. It subsequently becomes amalgamated with the two divisions of the ventral sinus, and establishes connections with the independently developed systemic lymphatic channels in a manner to be described fully in the detailed publication to follow this communication.

2. THE SYSTEMIC LYMPHATIC CHANNELS

The systemic lymphatic vessels of the reptilian embryo arise as numerous intercellular mesenchymal spaces, which become secondarily lined by endothelium, enlarge rapidly and become confluent with each other to form extensive lymphatic sinuses. These subsequently effect a secondary junction in the anterior part of the body with the jugular lymph sac, and through this establish their final entrance into the veins. The secondary and definite lymphatico-venous tap in this region is made by the caudal division of the ventral veno-lymphatic sinus reentering the precardinal vein at a point at which the same develops, in response to the jugular sac approach, a distinct rudimentary lymph-heart. In the area here considered these independently formed systemic lymphatic sinuses are chiefly divided into a dorsa and ventral group. The former develops around the dorsal aortae and, further caudad, surrounds the single aorta. The mammalian thoracic duct is the much reduced homologue of this set of dorsal periaortic sinuses. The ventral set of independently formed lymphatic channels, corresponding to the mammalian broncho-mediastinal trunk, develops along and around the divisions of the truncus arteriosus in the ventral coelomic region.

The development of the systemic lymphatic intercellular spaces, and their subsequent confluence into the extensive set of periarterial lymphatic channels, can be followed with the greatest clearness in reptilian embryos. They are from the beginning sharply defined and can be traced step by step to their full development. They are not complicated by close topographical relations to adjacent temporary embryonic venous plexuses, as in the mam-

mal, but develop independently by themselves in mesenchymal territory not occupied by haemal vascular elements. Hence their genetic history can be clearly followed and their successive stages easily interpreted. Moreover, they are, from the beginning, laid down in definite larger individual segments, which can be constantly identified as invariable structures in numerous embryos of approximately the same period. As a whole, the development of the systemic lymphatic system of the reptile, as compared with that of the mammal, presents the following main points of difference, and offers the corresponding advantages in a detailed study:

1. The mammalian systemic lymphatic vessels develop by the confluence of numerous small intercellular mesenchymal clefts and spaces, which enlarge, become lined by a lymphatic endothelium, and gradually join each other to form longer and longer segments of the future continuous lymphatic channels. The majority of these early lymphatic anlages appear in the mammalian embryo in close association with the embryonic veins, although in no sense *derived* from the same. This intimate relationship of developing lymphatic spaces and the associated venous plexuses has, in the previous publications quoted (1, 3, 4, 6, 8, 9, 10, 11), been defined as the *extraintimal type* of lymphatic genesis. This term is employed to sum up briefly the formation of a lymphatic anlage, surrounding, and in many cases subsequently entirely replacing topographically, an atrophying embryonic vein, in such a way that the lymphatic lumen is always *outside* the lumen of the decadent venule, and the lymphatic endothelium is an independent modification of the mesenchymal cells limiting the early lymphatic space, and *not derived* from a *pre-existing venous endothelium*. By far the greater number of the mammalian systemic lymphatic vessels are developed in this manner. At the same time, as previously described (loc. cit. 8, p. 413) in certain regions in the mammalian embryo lymphatic channels develop by confluence of intercellular mesenchymal spaces without this intimate topographical relation to embryonic veins, in fact in areas in which no extensive venous plexuses exist.

The reptile, in comparison with the mammal, shows relatively reversed conditions. In both lacertilian and chelonian embryos

the greater part of the enormously enlarged systemic lymphatic channels develops without any reference whatever to embryonic veins, in mesenchymal areas where the latter are extremely scanty or entirely wanting. A much smaller proportion of the entire system develops, on the prevalent mammalian plan, by confluence of perivenous or extraintimal lymphatic anlages, accompanying and surrounding temporary embryonic veins. This, for example, is clearly seen in the development of the extensive subcutaneous lymphatic plexus along the course of the lateral somatic vein and its tributaries in chelonian embryos.

The genetic processes are identical in mammal and reptile. In both the basic principle active in the development of the systemic lymphatic trunks is independent intercellular mesenchymal space formation, with independent origin of the lymphatic endothelium by direct modification of the mesodermal cells limiting the early spaces. In the reptile the greater number of the important resulting systemic lymph-channels develop without any relation whatever to embryonic veins, as periarterial sinuses, and only a minority of such channels follow and subsequently replace early venous radicles. The reverse obtains in the mammalian embryo, where most of the systemic channels develop primarily as extraintimal or perivenous spaces in the sense above defined, and only a small proportion of the entire system of lymphatic vessels lack this relationship to the embryonic veins in the early genetic stages.

The development history of the main reptilian systemic lymphatics is therefore comparatively easy to follow, because it is not complicated by this intricate interlacement with venous elements, and because hence the question of their direct origin from veins never even arises.

The reptilian embryo shows most conclusively, in the mutual relations of developing haemal and systemic lymphatic vascular channels, that the close ontogenetic association between the two in the mammalian ontogeny is purely an adaptation to special conditions here obtaining. The temporary embryonic venous plexuses of the mammal offer, in their regression and atrophy, mesenchymal lines of less resistance selected by the developing

perivenous lymphatic anlages. But both in mammal and reptile haemal and lymphatic channels are in their genesis established as separate and independent structures.

2. In the second place the mammalian systemic lymphatics arise as extremely numerous small intercellular spaces. It is only subsequently that these multiple anlages unite with each other to form longer and more distinct segments. In the reptilian embryo, on the other hand, the still separate main segments of the subsequently continuous lymphatic sinus are laid down from the beginning in definite mesenchymal areas, and increase within these areas by successively opening into the adjacent intercellular spaces, so that their continuous growth and extension can readily be followed. As a result the final union of these highly developed systemic lymphatic segments with each other and with the rudimentary jugular lymph hearts takes on the character of a much more definite and clear-cut process than is the case in the mammal, where the picture is less striking, owing to the far greater number and much smaller size of the individual components.

3. In still another respect the reptilian embryo possesses a distinct advantage over the mammal, namely in reference to the connection between the well-defined endothelial-lined lymphatic channels and the interstitial mesenchymal tissue spaces. In the mammalian embryo a lymphatic anlage in the earlier stages can often be followed for considerable distances as a distinct endothelial channel, which then appears to end blindly in indifferent mesoderm, to reappear after a shorter or longer interval in the next adjacent link of the still discontinuous chain which begins and ends in the same way. Presumably, in these stages, the lymphatic lumen opens into an intercellular space-plexus in the as yet undifferentiated interstitial tissue. This, however probable, is still an assumption and not capable of clear and uncontrovertible proof. On the other hand, the reptilian embryo in numerous regions, will show with absolute certainty the relation between a developing endothelial-lined lymphatic space and the, as yet indifferent, interstitial spaces bounded by unmodified mesenchymal cells. The lymphatic endothelium stops abruptly, with a clear-

cut, sharp outline, and a stoma leads from the lumen of the lymphatic channel directly and unmistakably into the intercellular network of spaces still surrounded by indifferent mesenchymal cells. Adjacent endothelial spaces approach each other in this way and finally unite. During this process the path of their mutual approach, along these interstitial tissue spaces, opens out more and more and the limiting mesenchymal cells assume successively typical endothelial characters. There is no sprouting on the part of the preexisting endothelium. Its direct continuity, along the path of future extension, with the as yet unmodified mesenchymal cells can be definitely determined, and every stage of the process can be closely observed and controlled by any number of corresponding observations on different embryos of the same general period.

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THE CULTIVATION OF TISSUES FROM CHICK EMBRYOS IN SOLUTIONS OF NaCl, $CaCl_2$, KCl AND $NaHCO_3$

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TWENTY-FOUR FIGURES

Having found that tissues from chick embryos grow readily in artificial media, nutrient agar and bouillon,[1] the next step was the attempt to cultivate such tissues in media all the constituents of which are known. In collaboration with Dr. Arthur Koelker we were able to obtain excellent growth in combinations of amido-acids and polypeptids of known constitution, in Locke's solution. Locke's solution with maltose and dextrose was then tried with such good results that Locke's solution was attempted with the very startling discovery that these embryonic tissues grow readily in the Locke's solution and various combinations of NaCl, $CaCl_2$, KCl, and NaH CO_3 as indicated in table 1.

So far the cultures in salt solutions have not grown as extensively as those in Locke's solution plus dextrose or maltose or the amido-acids and polypeptids, nor have these given as extensive growth as nutrient agar or bouillon, and these in turn have not been as fine or lived as long as those in plasma.

It is to be hoped that an artificial medium will be found as satisfactory as the plasma, for the advantages are obvious if one can work with a known medium in the investigation of the many new problems, which suggest themselves.

[1] On the growth of embryonic chick tissues in artificial media, nutrient agar and bouillon. Johns Hop. Hospital Bul., April, 1911.

The following account of the growth of tissues in salt solutions is fragmentary and work is being continued along various lines such as the differences in behavior of different organs in various solutions and the attempt to obtain an optimum solution for each tissue.

THE METHOD

Usually 10 cc. of each solution is made up from stock solutions. These are autoclaved and then poured into warm Petri dishes. Small pieces several millimeters in diameter are cut out of the various organs of the embryo and put directly in the solution. Each piece is then cut up into a number of much smaller pieces a fraction of a millimeter in diameter. With a capillary tube one or more are drawn up and transferred with a small drop of the solution onto a cover-glass and then inverted, to form a hanging drop, over a hollow ground slide on which has been placed a ring of stiff vaseline. The slides are kept at about 40° C.

The embryos are dissected under aseptic conditions. Instruments, slides, covers and capillary tubes are sterilized in a free flame.

Ordinary vaseline can be stiffened by the addition of paraffin.

The cultures are examined on a warm stage.

Permanent preparations are made by fixing the coverslips in osmic vapor and staining in Ehrlich's haematoxylin. The growths adhere to the coverslips and there is practically no distortion.

All photographs and drawings except those of the nerves were made from fixed preparations.

Eighty-five culture media were prepared at different times and either six or twelve cultures made from each, making in all about 600 slides, which were examined daily. Among the eighty-five are repetitions to test more carefully the medium or the growth of tissues from chicks of different ages. The earlier cultures contain only liver, the more recent ones usually have two or more tissues, such as liver, intestine, kidney, heart and spleen, in the same hanging drop.

It will be seen from the table that tissues did not grow in solutions without NaCl; on the other hand, tissues grow readily with-

TABLE 1

Showing percentages of salts

L = liver, I = intestine, K = kidney, H = heart, S = spleen

	NaCl	$CaCl_2$	KCl	$NaHCO_3$	NUMBER OF CULTURES	NUMBER WITH GROWTH	AGE OF CHICK	ORGAN	DURATION OF GROWTH	EXTENT OF GROWTH
(1) H_2O.					6	0	10	L,I,K		
(2).....	0.3375				6	0	8	L, I		
(3).....	0.6525				6	0	8	L, I		
(4).....	0.75				12	8	8	L	2	Slight
(5).....	0.9				12	2	5	L	2	Extensive
(6).....	1.575				6	0	8	L, I		
(7).....	2.025				6	0	8	L, I		
(8).....				0.005	6	0	10	L, I K		
(9).....				0.015	6	0	10	L, I K		
(10).....				0.05	6	0	10	L, I K		
(11).....	0.75	0.02			12	0	8	L		
(12).....	0.9	0.00625			6	0	13	L		
(13).....	0.9	0.00625			6	5	8	L, I	3	Extensive
(14).....	0.9	0.0125			6	0	13	L		
(15).....	0.9	0.025			6	3	8	L, I	3	Extensive
(16).....	0.9	0.125			6	6	8	L, I	3	Extensive
(17).....	0.675		0.105		6	6	8	L, I H	5	Good
(18).....	0.9			0.05	6	0	10	L, I K		
(19).....		0.0625	0.105		6	0	8	L, I		
(20).....		0.125	0.21		6	0	8	L, I		
(21).....		0.25	0.42		6	0	8	L, I		
(22).....			0.105	0.05	6	0	10	L, I K		
(23).....		0.025	0.042	0.02	6	0	8	L, I		
(24).....		0.075	0.126	0.02	6	0	8	L, I		
(25).....		0.125	0.315	0.1	6	0	8	L, I		
(26).....	0.657		0.105	0.05	6	6	8	L,I,H	2–3	Good
(27).....	0.675	0.125		0.1	6	1	8	L, I	2	Slight
(28).....	0.9	0.025		0.02	6	6	8	L, I	3–4	Extensive

TABLE 1—Continued

	NaCl	$CaCl_2$	KCl	$NaHCO_3$	NUMBER OF CULTURES	NUMBER WITH GROWTH	AGE OF CHICK	ORGAN	DURATION OF GROWTH	EXTENT OF GROWTH
(29)	1.35	0.05		0.04	6	6	8	L, I	3–4	Extensive
(30)	0.9	0.00625	0.021		6	3	13	L	2–3	Good
(31)	0.9	0.00625	0.042		6	3	13	L	2–3	Fair
(32)	0.9	0.0125	0.021		6	4	13	L	2–3	Slight
(33)	0.9	0.0125	0.04		6	6	13	L	3–4	Good
(34)	0.9	0.025	0.021		6	0	13	L		
(35)	0.9	0.025	0.042		6	2	13	L, H	2	Fair
(36)	0.9	0.0125	0.021	0.01	6	4	13	L, I	2–3	Good
(37)	0.9	0.0125	0.021	0.02	6	4	13	L, I	2–3	Extensive
(38)	0.9	0.025	0.021	0.01	6	6	13	L, S	3–4	Good
(39)	0.9	0.025	0.021	0.02	6	6	13	L, I	3–4	Good
(40)	0.9	0.025	0.042	0.01	6	6	13	L, I	2–3	Good
(41)	0.9	0.025	0.042	0.02	6	4	13	L, I	2–3	Good
(42)	0.9	0.025	0.042	0.02	6	6	8	L, I	4	Good
(43)	0.9	0.025	0.042	0.02	12	12	7	L	6	Extensive
(44)	0.9	0.025	0.042	0.02	6	4	9	L	4	Slight
(45)	0.9	0.025	0.042	0.02	6	5	5	L	3	Extensive
				Sodium decreased						
(46)	0.675	0.025	0.042	0.02	6	5	8	L, I	2–3	Extensive
(47).	0.45	0.025	0.042	0.02	6	4	8	L, I	2	Good
(48)	0.225	0.025	0.042	0.02	6	0	8	L, I		
(49)	0.675	0.0625	0.105	0.05	6	6	8	L,I,H	1–2	Good
(50)	0.675	0.125	0.21	0.1	6	6	8	L,I,H	4–5	Extensive
(51)	0.675	0.125	0.21	0.1	12	12	7	L	2	Extensive
(52)	0.225	0.150	0.252	0.12	6	6	8	L, I	3	Extensive
				Sodium increased						
(53)	1.	0.025	0.042	0.02	12	8	4	L	2–3	Extensive
(54)	1.1	0.025	0.042	0.02	14	12	7	L	3–4	Extensive

TABLE 1—Continued

	NaCl	$CaCl_2$	KCl	$NaHCO_3$	NUMBER OF CULTURES	NUMBER WITH GROWTH	AGE OF CHICK	ORGAN	DURATION OF GROWTH	EXTENT OF GROWTH
(55)	1.2	0.025	0.042	0.02	12	11	7	L	3–5	Extensive
(56)	1.125	0.025	0.042	0.02	6	6	7	L	2	Fair
(57)	1.23	0.025	0.042	0.02	6	2	7	L	1–2	Slight
(58)	1.2375	0.025	0.042	0.02	6	6	8	L, I	8–9	Extensive
(59)	1.3	0.025	0.042	0.02	12	5	8	L	2	Extensive
(60)	1.35	0.025	0.042	0.02	6	5	7	L	2–3	Extensive
(61)	1.45	0.025	0.042	0.02	12	0	8	L		
(62)	1.4625	0.25	0.042	0.02	6	6	8	L, I	8–9	Extensive
(63)	1.46	0.025	0.042	0.02	6	3	9	L	3	Extensive
(64)	1.5	0.025	0.042	0.02	12	0	8	L		
(65)	1.57	0.025	0.042	0.02	6	0	9	L		
(66)	1.575	0.025	0.042	0.02	6	0	15	L		
(67)	1.585	0.025	0.042	0.02	6	6	8	L,H,I	8–9	Extensive
(68)	1.6975	0.025	0.042	0.02	6	1	8	L,H,I	3	Slight
(69)	1.7	0.025	0.042	0.02	12	0	7	L		
				Calcium decreased						
(70)	0.9	0.00625	0.042	0.02	6	4	13	L, I	2–3	Good
(71)	0.9	0.0125	0.042	0.02	6	3	13	L,I,S	3	Good
				Calcium increased						
(72)	0.9	0.035	0.042	0.02	6	2	15	L	2–3	Good
(73)	0.9	0.04	0.042	0.02	6	2	15	L	2-3	Slight
(74)	0.9	0.045	0.042	0.02	6	1	15	L	2–3	Extensive
(75)	1.575	0.05	0.042	0.02	6	0	15	L		
(76)	0.9	0.06	0.042	0.02	6	2	15	L	2–3	Good
(77)	0.9	0.075	0.042	0.02	6	2	15	L	2–3	Fair
(78)	0.9	0.225	0.042	0.02	6	0	15	L		
(79)	0.45	0.0125	0.021	0.01	12	6	8	L	3	Good
(80)	0.225	0.00625	0.0105	0.005	12	0	8	L	0	

TABLE 1—Continued

Isotonic solutions

	NaCl	$CaCl_2$	KCl	$NaHCO_3$	NUMBER OF CULTURES	NUMBER WITH GROWTH	AGE OF CHICK	ORGAN	DURATION OF GROWTH	EXTENT OF GROWTH
(81).....	1.167	0.025	0.042	0.02	6	5	9	L, I	3	Extensive
(82)	0.0	1.575	0.042	0.02	6	?2	9	L, I		1 or 2 cells
(83)	0.032	1.532	0.042	0.02	6	0	9	L, I		
(84)	0.0	0.025	1.545	0.02	6	0	9	L, I		
(85)	0.03	0.025	1.503	0.02	6	0	9	L, I		

out either $CaCl_2$ or KCl, or $NaHCo_3$. The percentage of NaCl in the various solutions may vary from 0.225 to 1.6975. The cultures seem to live longest in the higher percentages. The percentage of $CaCl_2$ may vary from 0 to 0.15 and even a higher percentage may allow growth, for the growth with 0.15 per cent was quite extensive, showing that the limit was not reached. The percentage of KCl may vary from 0 to 0.252 but here likewise the upper limit has not been determined. The percentage for $NaHCo_3$ may vary from 0 to 0.12.

Growth can take place in NaCl alone, in NaCl in combination with $CaCl_2$ or KCl or both, in NaCl and $NaHCo_3$ with either $CaCl_2$ or KCl or both. Only one combination of NaCl and $NaHCo_3$ was tried, no growth occurred but there are probably combinations in which growth will take place.

NaCl is apparently the most essential salt and although the others are not necessary the maximum growth was attained when all four were used. With the 1.585 per cent growth did not begin until the second day, with 1.6975 per cent it did not appear until the third day.

THE CHARACTER OF GROWTH

Much uncertainty exists as to exactly which kind of cells give rise to the various types of growth. Most organs have a variety of cells any one of which may behave in a number of ways. There is considerable variation in the character of the growth and in the character of the individual cells both in different cultures and from the same piece.

The table is far from a complete one and many more combinations remain to be tried out. Many more cultures should also be made under as similar conditions as possible with some of the solutions already tried, before correct conclusions can be drawn as to the effect of various combinations on growth. Two pieces of tissue taken from the same organ of the same embryo, cut into small pieces in the same dish and transplanted into the same drops will show sometimes marked differences in growth. The main difference in the preparation consists in the cutting up of the pieces with the scissors. There are also differences in the size and thickness of the drop.

These salt solutions can hardly be considered as nutrient media but correspond more to what Loeb designates as 'protective media.' It is quite remarkable that cells will grow in such widely different solutions where the osmotic pressure must vary considerably. It will be interesting to determine the osmotic pressures of these solutions.

Such growth as does take place will probably be limited by the amount of stored up food in the cells as well as by the medium. In most of the solutions growth seems to be accelerated during the first twenty-four or forty-eight hours as compared with that in plasma. In some of the solutions, however, as has been noted, growth is retarded.

The small pieces, which are to be planted are often kept for an hour or more in 10 cc. of solution before transplanting. The plasma, blood and lymph are thus well washed out, and so the later growth of cells into the solution is not to be explained by the influence of escaped plasma about the piece.

It is difficult to distinguish between growth and the migration of cells from the transplanted piece. Active growth is indicated

by membrane formation of all types and by the extensive radiation and reticular formations especially when mitosis is found here and there as it is in the stained preparations. Likewise, the outgrowth of the nerve fibers undoubtedly shows that growth occurs. What proportion of the cells merely wander outward from the piece without cell-division cannot be readily determined. Both mitotic and amitotic cell division take place.

The liver from the older embryos does not seem to grow nearly as well in the various solutions as that taken from younger ones. The intestine on the other hand grows about equally well whether it be taken from eight or thirteen-day embryos.

In many of the solutions maximum growth occurred during the first twenty-four hours but in Locke's solution with the higher percentage of NaCl growth is delayed and prolonged.

The most common form of growth consists of radiating and anastomosing cells, some of these may become entirely free in the surrounding area either singly or in groups. All gradations are found between such radiations and loose reticular formations and a continuous syncytial membrane one layer thick. The reticular formation may consist of rather broad cells with numerous processes or the cells may be exceedingly thin, the nucleus bulging out on either side. Such cells often have processes many times the length of the cell.

There is a striking similarity between the growth of normal tissues of embryo chicks in salt solutions, bouillon, nutrient-agar, and plasma and those pictured by Lambert and Hanes[2] for the growth of rat and mouse sarcoma and carcinoma in plasma.

The growing cells in salt solutions differ from those in plasma in one very noticeable feature, namely, the absence of the accumulation of fat or oil globules within the cell body which is so characteristic of plasma cultures.

In addition to these forms of growth the intestine often gives rise to a compact membrane with small nuclei. The cell borders can often be seen in the living specimens. They remind one very much of peritoneal mesothelium. The spleen, on the other

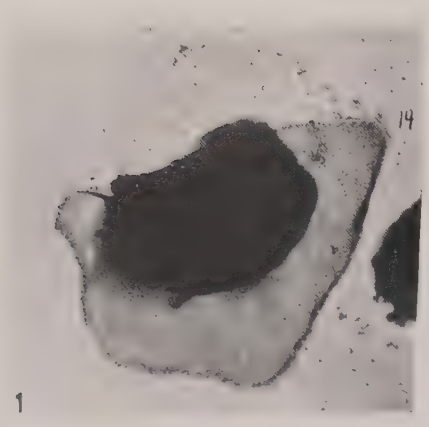
[2] Jour. Exp. Med., May, 1911.

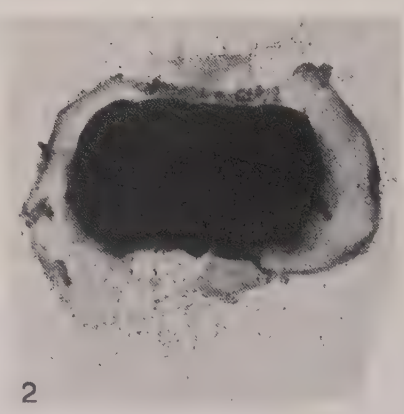
hand, usually gives rise to many migrating cells, which move outward in a band.

In one culture of an eight-day embryo the outgrowth of sympathetic nerve fibers was followed. When first observed 18 hours after the culture was made they had already grown out quite extensively. During the next twenty-four hours there was a great increase in the number and length of the fibers. The process of growth in this solution (29) was essentially the same as that previously observed in a plasma medium. The growing fibers seem to make and break anastomoses with other fibers or to pass by each other without anastomosing. During the third day bead-like degeneration began.

Growth apparently takes place as well in fluid media as in the more solid lymph, plasma or agar media. The fibrin threads are not necessary either for the outgrowth of nerve fibers or the various types of cells. The outgrowing cells do, however, often creep along on the coverglass and the nerve fibers may have done so as well. In the hanging drop cultures the long radiating fibers go upward to the underside of the coverglass while in Petri dish cultures they often grow down to the bottom of the dish and anchor the piece of tissue quite firmly.

The adhesion of the growth to the cover slip probably explains why one can get such good permanent preparations, that are neither washed off nor distorted in the staining and dehydrating.





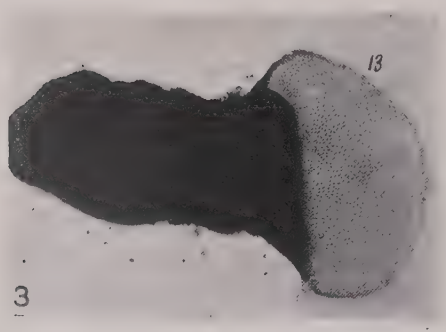


Fig. 1 From series 71 (see table). Twenty-hour culture of intestine, showing compact peritoneal? membrane and connective tissue? or syncytial membrane. × 60 diameters.

Fig. 2 From series 39. Twenty-hour culture of intestine, showing a similar membrane and connective tissue ? growth. × 60 diameters.

Fig. 3 From series 42. Eighteen-hour culture of intestine, showing compact membrane only. × 60 diameters.

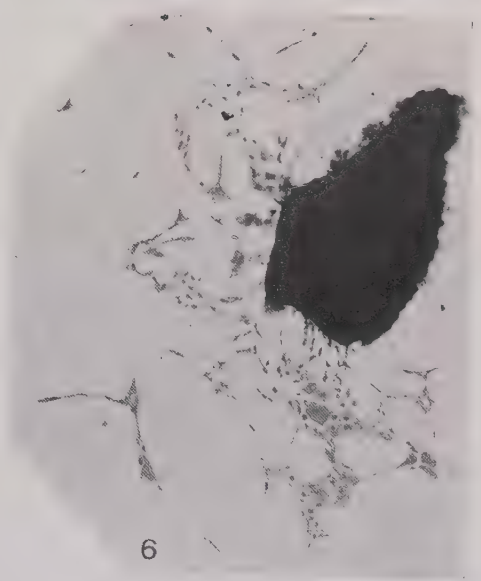


Fig. 4 From series 58. Two-day culture of liver, showing radiating strands of connective tissue. × 60 diameters.

Fig. 5 From series 37. Twenty-hour culture of intestine. × 60 diameters.

Fig. 6 From series 76. Three-day culture of liver, showing anastomosing islands of new cells. × 60 diameters.

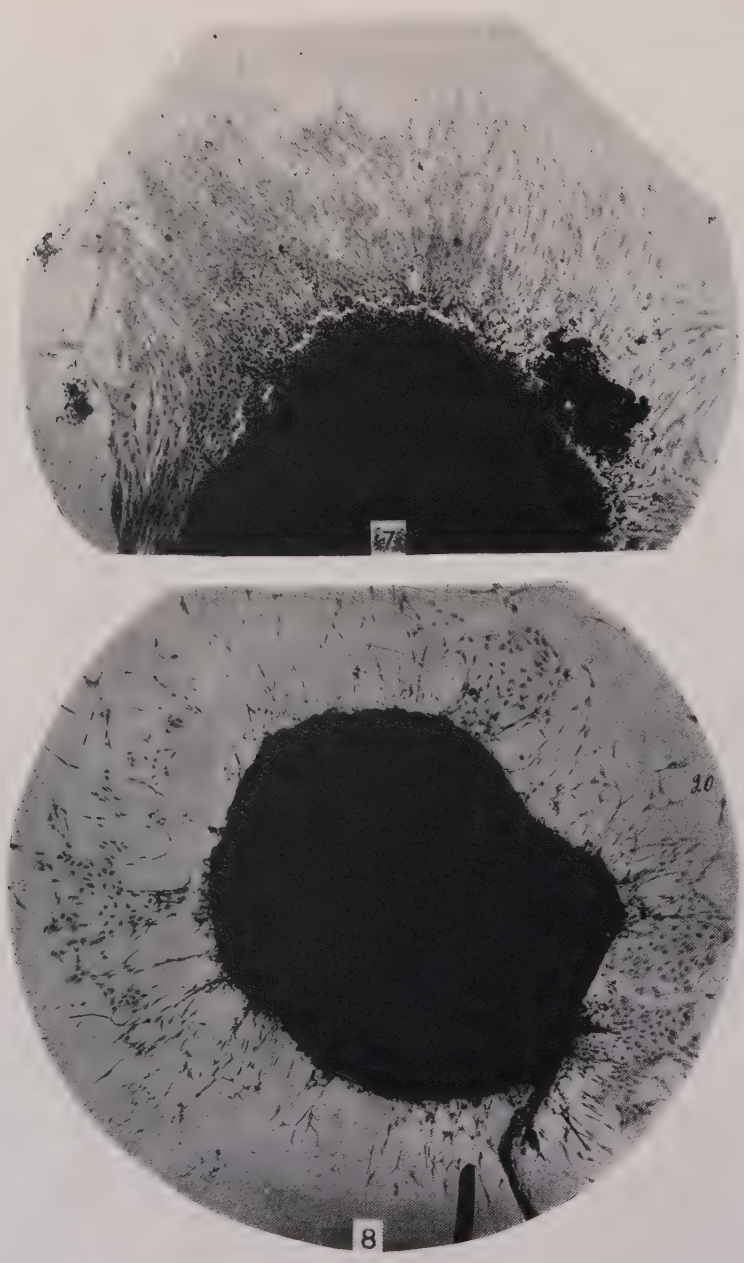
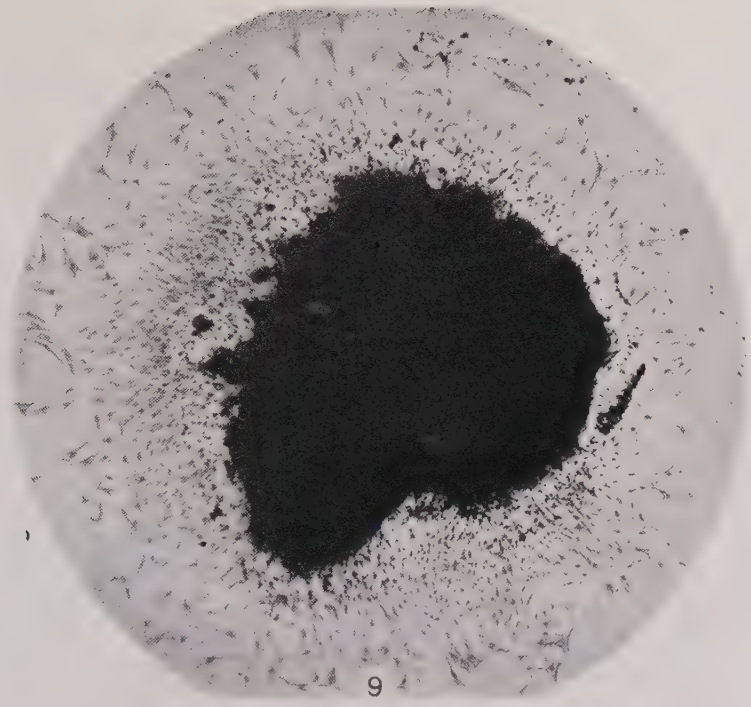


Fig. 7 From series 67. Three-day culture of liver, showing both radiating strands and syncytial formation. × 60 diameters.

Fig. 8 From series 45. Twenty-four hour culture of liver, showing a different type of radiation with patches of syncytium. × 60 diameters.

Fig. 9 From series 62. Two-day culture of liver, showing extensive radiation and syncytium. × 60 diameters.

Fig. 10 From series 51. Twenty-hour culture of liver. × 60 diameters.



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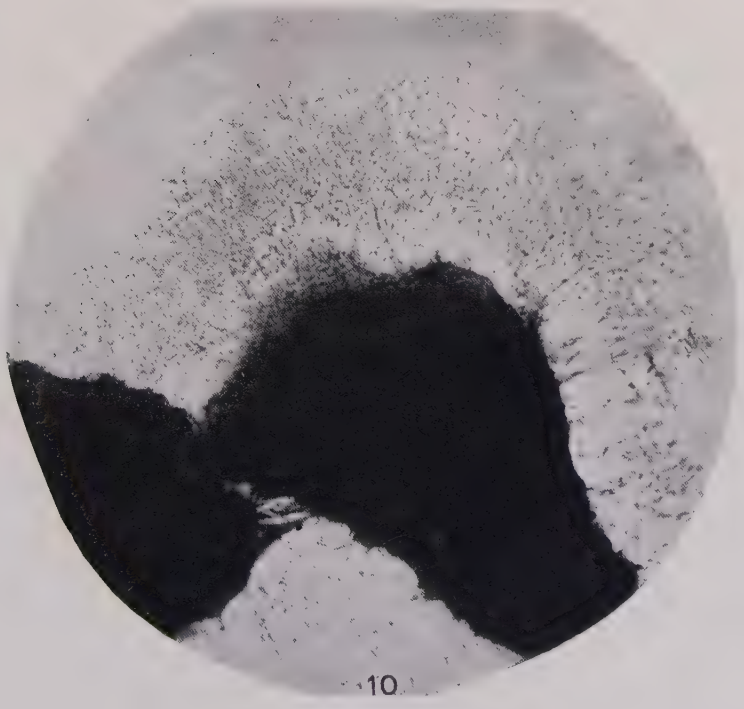

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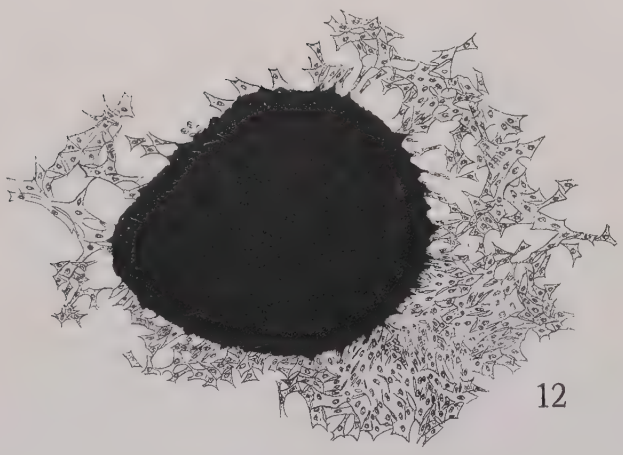


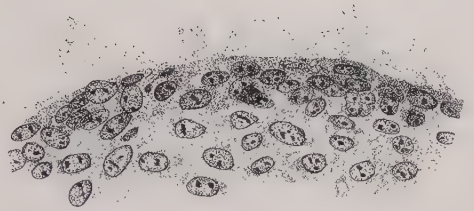
Fig. 11 From series 39. Forty-four-hour culture of liver showing syncytial membrane and migrating cells. × 60 diameters.

Fig. 12 From series 55. Twenty-four-hour culture of liver. × 60 diameters.

Fig. 13 From series 42. Enlarged drawing of the edge of the compact membrane of fig. 3, showing the thin protoplasmic margin. × 425 diameters.

Fig. 14 From series 71, (see fig. 1, 14). Enlarged drawing of the junction of the compact membrane with the syncytial membrane of fig. 1. × 425 diameters.

Figs. 15–18 From series 37 (see fig. 5). Enlarged drawings from fig. 5, 15 of the syncytial membrane with nuclei full of chromatin granules; 16, syncytial membrane; 17, branched spindle cells; 18, loose syncytial net. × 425 diameters.



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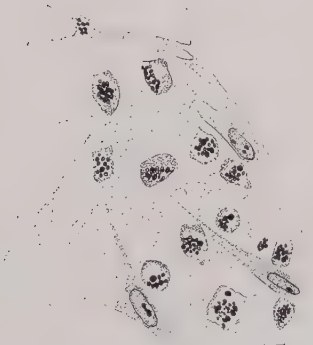

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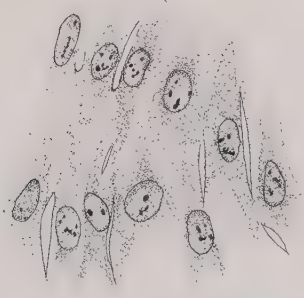

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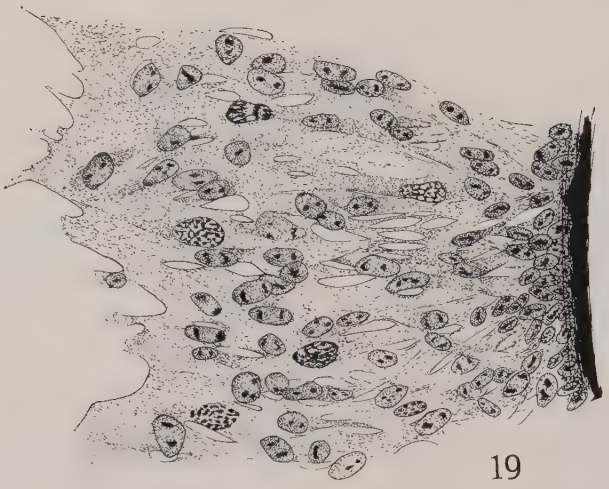

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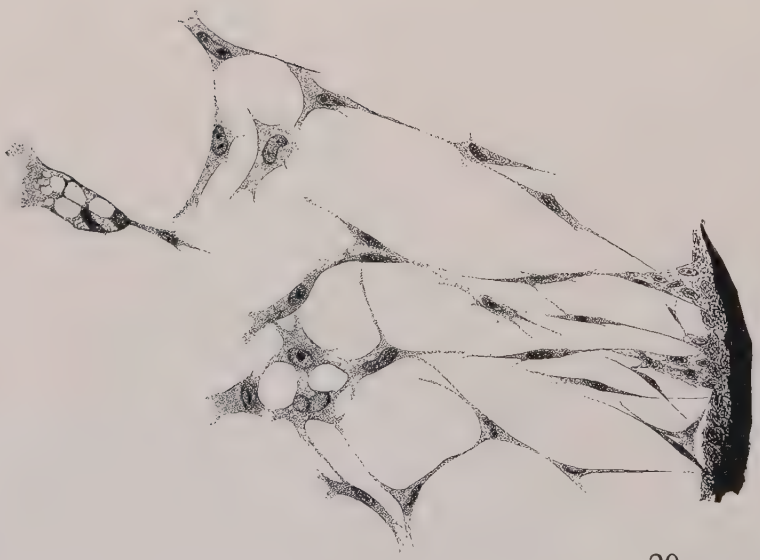

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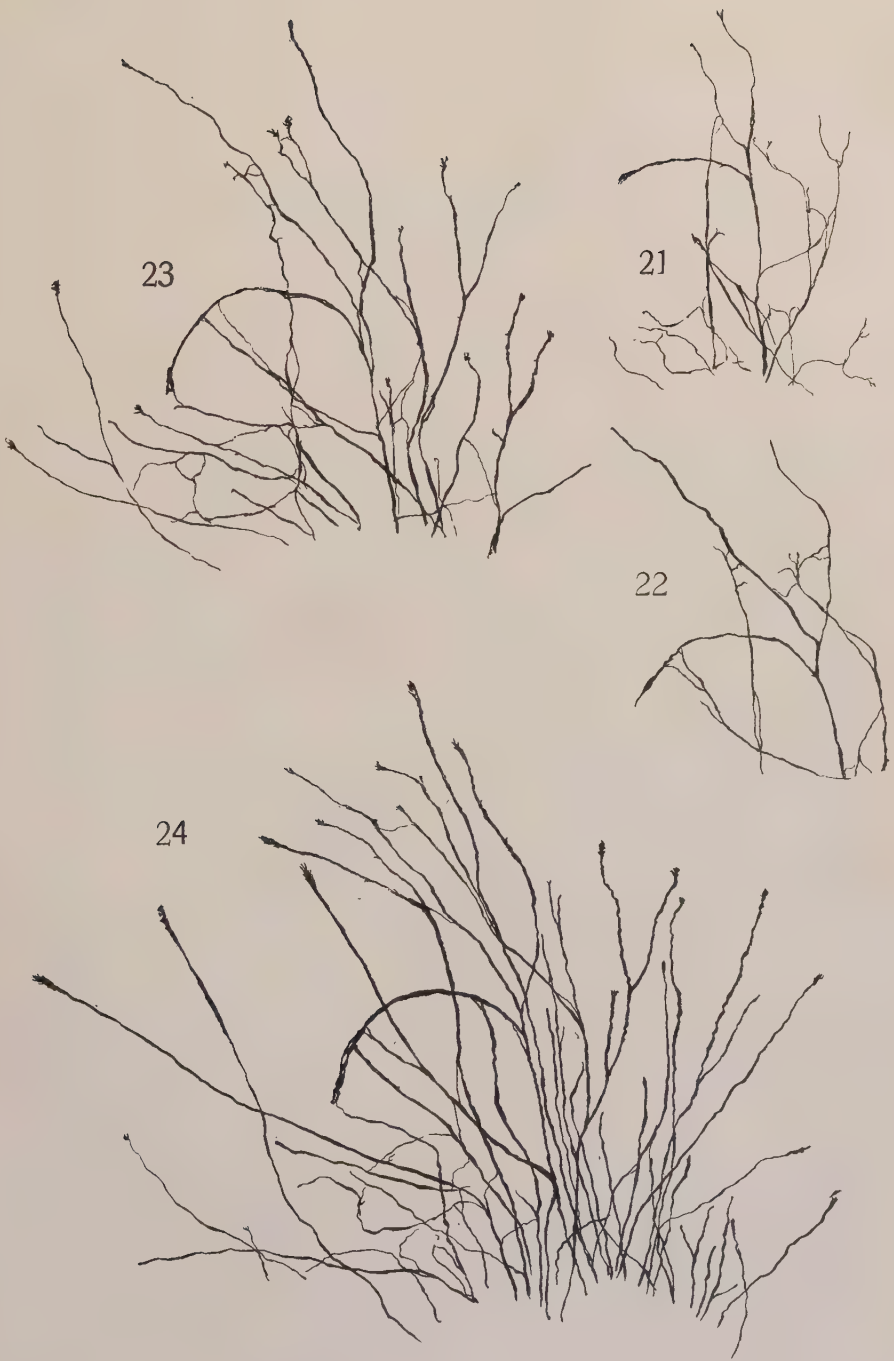
Fig. 19 From series 65. Three-day culture showing syncytial membrane. × 325 diameters.

Fig. 20 From series 45, (see fig. 8, 20). Enlarged drawing of fig. 8, showing the reticular formation. × 325 diameters.

Figs. 21–24 From series 29. Four drawings of the outgrowth of sympathetic nerve fibers made 18, 19, 20 and 41 hours after the piece was transplanted; 22 shows only a small area. × 300 diameters.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NOTE ON THE BLASTODERMIC VESICLE OF THE OPOSSUM

CHARLES S. MINOT

From the Laboratory of Comparative Anatomy, Harvard Medical School

TWO FIGURES

The publication of Professor Hill's very valuable monograph[1] on the early development of Marsupials renders it advisable to report on the structure of several opossum blastocysts of about 1.0 mm. diameter belonging to the Harvard Embryological Collection. In structure these vesicles agree essentially with the descriptions of Professor Hill, although in a stage, which is intermediate between those studied by him. They afford confirmation and some extension of his important results.

Two of the vesicles were presented by Professor McClure, whose generosity it is a pleasure to acknowledge gratefully. They had been very successfully preserved with Flemming's fluid. One of these was torn with dissecting needles into several fragments, which were then mounted in damar, to furnish surface views; it forms no. 1697 in our collection. The other is to be cut into serial sections for the Harvard Embryological Collection.

The remaining vesicles were collected by Dr. J. L. Bremer from a single female. They were preserved in Zenker's fluid. Two of them were found in series 835, of a pregnant uterus. Two were removed from the uterus before preservation.

All of the specimens are close to 1.0 mm. in diameter, but the size of the two cut *in utero* is estimated only, for they are somewhat distorted and of course have been made smaller by the action of paraffine, in which the specimen was imbedded. The vesicles

[1] Quarterly Journal of Microscopical Science, vol. 56, p. 1–134. December, 1910.

are all enclosed by a thin zona pellucida, which appears homogeneous. In the sections its outer surface is seen to bear widely separated minute protuberances each about the size and somewhat of the form of an endothelial nucleus, but having the same optical appearance as the substance of the zona. Sometimes outside the zona there is a thin badly stained layer of cells, which may be a remnant of the corona radiata. In the alcoholic specimens the zona is smooth and forms an almost perfectly spherical vesicle. In the sections it is more or less crumpled.

The blastocysts are completely didermic throughout, but I find no trace of a middle layer, or of anything resembling a primitive (or so-called Hensen's) knot. The cellular layers are fitted close against the zona, although in the sections they appear artificially and irregularly separated from it. The inner layer is complete, or nearly so, is thin and has the nuclei widely spaced. The outer layer is complete, but comprises two areas, one smaller, the other larger. The smaller area forms an almost circular polar cap, which occupies about one-eighth of the surface of the ovum, but varies in size in the different vesicles; it is conspicuous owing to its darker appearance. The larger area completes the blastocystic wall and is lighter in effect, and further differs from the smaller area by having scattered over it light spots, which viewed with a hand lens seem to be minute round holes.

It seems safe to conclude that we have to do with a true ectoderm, an entoderm and an embryonic shield in an early stage.

The shield is nearly circular in outline. Viewed from the surface, fig. 1, B the nuclei appear closely crowded together, varying considerably in form and diameter, but all rounded in outline. The figure suggests that they are all at one level, but this can be demonstrated by the use of the fine adjustment not to be the case. In my book "Age, Growth, and Death," p. 175, I have pointed out that the nuclei, specifically of the rabbit, pass through definite ontogenetic stages. In what there is given as the first stage, fig. 61, nos. 1, 2, 3 and 4 the nuclei have a network structure, and one, two or three nucleolus-like or plassome masses. In the next stage, nos. 5-8, the network has become coarser and the meshes wider. All the nuclei in all the layers in these opos-

sum resemble in structure the first stage of the rabbit nuclei. In the surface view of the shield of the opossum, I am unable to recognize any cell boundaries, which can be identified with certainty as such, but the reticulated protoplasm is easily observed between the nuclei. With an oil immersion objective and careful focusing, one can observe the entodermal nuclei of the shield; they can be easily recognized by their greater diameter. They are quite widely separated from one another. The edge of the embryonic shield is very sharp. I have noticed no alteration

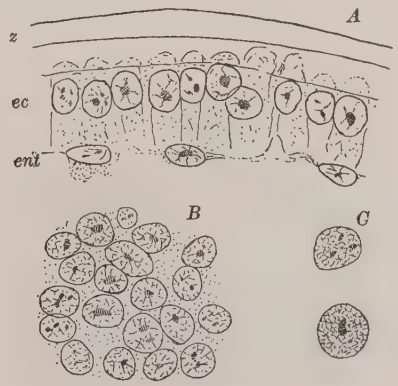

Fig. 1 Vesicles of 1.0 mm. diameter of opossum. A. Section of the embryonic shield. *z*, zona pellucida. *ec*, ectoderm. *ent*, entoderm. H. E. C. Series 835, section 30. B. Surface view of embryonic shield. H. E. C. Series 1697. C. Entodermal nuclei of extra-embryonic region. H. E. C. Series 1697. All × 500 diams.

in the entoderm, the transition being effected apparently only by alteration of the ectodermal cells. Around the edge of the shield is an irregularly wavy fine boundary line, which marked the limit of the area, and the outer edges of the peripheral row of cells, the protoplasm of which is denser and therefore darker in the preparations than that of the rest of the shield. The cells next the boundary row are often intermediate in character.

Sections of the shield, fig. 1, A, show that the ectoderm consists of high narrow cylinders, between which imperfect cell-

boundaries can be observed. The nuclei all lie towards the upper or outer ends of the cells, but at various levels. They have shrunk away from the zona, and the space between contains more or less granular coagulum, which tends to make a separate cap over each cell as shown in the figure. The entoderm is a thin layer upon the underside of the shield, fitted very closely against the outer layer. The entodermal nuclei are flattened, which accounts for their larger diameter as seen in surface views. The average vol-

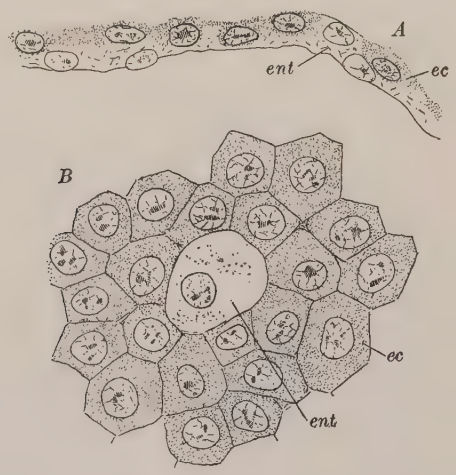

Fig. 2 Vesicles of 1.0 mm. diameter of opossum. A. Section of the extra-embryonic area. H. E. C. Series 835, section 30. B. Surface view of extra embryonic area. H. E. C. series 1697. *ec*, ectoderm. *ent*, entoderm. Both × 500 diams.

ume of the nuclei in the two layers is probably about the same. The larger diameter of the entodermal nuclei in surface view will be recognized if the two nuclei shown in fig. 1, C are compared with those of the ectoderm in fig. 2, B. All the nuclei in the surface views are larger than in the sections, which were made in paraffine, because embedding in paraffine reduces the diameter of all structures often 25 per cent, which involves a reduction of the volume to almost one-half. The effect of the use of paraffine in the size of cells in not always heeded sufficiently.

The extra embryonic ectoderm differs remarkably from that of the shield. It is a thin layer, fig. 2, A. In surface views fig. 2, B, the cells occupy relatively large areas, and are everywhere marked off from one another by sharp-cell boundaries; the cells are polygonal and usually five-sided, sometimes six-sided rarely four-sided. The most striking peculiarity however of the layer are the minute rounded clear spaces, before referred to, one of which is represented in fig. 2, B. They are scattered singly, vary somewhat in size and outline, and are bounded each by eight to ten or more polygonal cells. Every space is occupied by a pale loosely reticulated protoplasm, in which is lodged usually a single nucleus. A few spaces contain two nuclei.

In sections stained with alum cochineal and orange-G, fig. 2, A, the ectoderm appears deeply stained, and the entoderm pale. Now and then the ectodermic layer is interrupted and a lightly stained cell interpolated. This cell is continuous with the entodermal layer and of the same character as the entodermal cells. One is forced to the conclusion that the ectoderm is not continuous, but that there are small gaps in it each of which is filled up by the entoderm. The entoderm is bounded internally by a well defined continuous line, which seems to mark the presence of a membrane. When the one of the entodermal cells comes to the surface it has a similar line as its external boundary, but no such line appears at the edge of the darker ectodermal cells.

The structure of the opossum blastocysts differs considerably from that found by Hill in Dasyurus. Although the former are only one millimeter in diameter, they are completely didermic. In the latter the extra-embryonic entoderm is in process of formation in vesicles of 4.5–5.0 mm. Hill writes, p. 69, "Even in vesicles of 7–7.5 mm. in diameter a unilaminar patch may still occur at the lower pole, but in vesicles 8.5 mm. in diameter the entodermal lining appears always to be complete." Still more remarkable are the cytological differences between the two forms found in the extra-embryonic area. In both species the area comprises two kinds of cells, first, a larger more lightly staining variety; second, a smaller variety with denser more granular and more deeply staining cytoplasm. The first variety forms the

ectoderm in Dasyurus, the entoderm in the opossum, and conversely the second variety forms the entoderm in the Dasyurus, the ectoderm in the opossum, (see Hill, *l. c.*, p. 56ff). Hence we must conclude that the two varieties of cells despite their similarities of appearance, are not homologous in the two species of animals. The two animals are alike in the unique mingling of the cells of their two germ-layers so that both layers in early stages are in immediate contact with the zona pellucida. This condition seems extraordinary, because nothing similar has been observed in any other class of vertebrates. For the present we are unable to give any morphological explanation of the strange fact that in Marsupials the innermost germ-layer at least temporarily and in part has acquired an external superficial position.

Hill's discovery that in the Marsupials there is no complete larval envelope or trophoblast renders it extremely difficult to accept Hubrecht's hypothesis that the trophoblast is a primitive closed envelope. That the trophoblast in Hubrecht's sense is a characteristic of the Eutheria, and probably all Eutheria, we must accept as established by Hubrecht's brilliant studies. Hill discusses in chapter 7 of his memoir the question whether a trophoblast in Hubrecht's later sense occurs in other vertebrates, and reaches a negative conclusion. As Hill's discussion is able and impartial, it need not be prolonged here, but I may add that his explanation of the origin of the entypic development of the Eutheria seems to me the most satisfactory yet offered and probably correct. Briefly the explanation assumes that in all mammals at the close of segmentation there is a cluster of formative cells and an extra-embryonic layer completing the wall of the blastocyst and becoming the extra-embryonic ectoderm. In the Eutheria in consequence of the loss of the yolk *and of the egg shell* the formative cluster has been pushed in, making the so-called inner cell-mass, and is temporarily covered by the extra-embryonic layer (Hubrecht's trophoblast.)

THE VOLUME OF THE VENTRICLES OF THE BRAIN

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ONE FIGURE

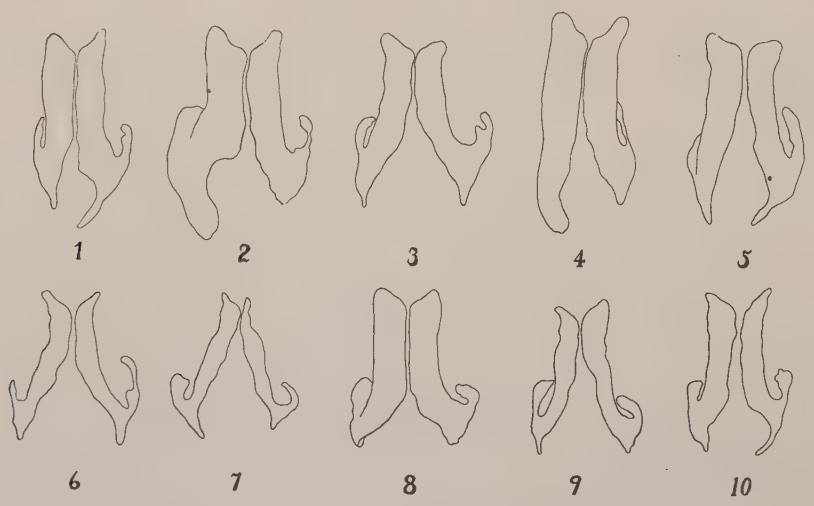
In a previous paper[1] a method was described by which Wood's metal casts of the ventricles of the brain can easily be made; and in a comparison of casts from five different brains it was observed that wide variations existed between the different casts, and between the two sides of the same cast. It was noted that the linear dimensions of the left anterior horn and body exceeded those of the right side, that the left posterior horn was more extensive in a majority of the casts, and that in the inferior horn the excess in dimensions was in favor of the left side as many times as of the right. Since then other casts of different brains have been made with the idea of obtaining a series for a comparative study of the casts themselves, and of their relations to the brains from which they were obtained. It is the intention in this paper to report the results of volume measurements of ten casts, together with the brain-weights, as a preliminary to the further study of the ventricles.

The method employed in obtaining the casts was slightly modified from that previously described. The brains were hardened in formalin, and after removal from the solution were allowed to drain for five minutes. The weight of each was taken before sectioning. Coronal sections were made through the genu of the corpus callosum, the foramina of Monro, and the splenium of the corpus callosum, thus dividing the brain into four sections. The parts of the ventricles contained in each section were cast sepa-

[1] Harvey, R. W. A cast of the ventricles of the human brain. Anat. Rec., vol. 4, no. 10, Oct., 1910.

rately in order to facilitate subsequent removal of the cast without destruction of the brain tissue, which was preserved for further study. The parts of the respective casts were afterwards joined together to form entire casts.

Outlines of the casts showing some of the variations are given in fig. A. It is to be observed that the two sides of the same cast are different in contour, and in a majority of cases more developed on the left side than on the right. The possibility of an internal hydrocephalus producing the very noticeable difference between



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the two sides of the cast numbered 2 is not to be overlooked. In all other cases normal conditions prevail so far as it is possible to determine. It may be seen at a glance that all the casts except 1 and 9 have an anterior horn larger on the left side than on the right.

After entire casts had been obtained, the next step was to determine their volumes. These were found by the displacement of water, and the measurement of the volume of water displaced. Each cast was cut with a saw into parts corresponding to the anatomical divisions of the ventricles. The lateral ventricles were

separated from the third ventricle at the foramina of Monro, and each lateral ventricle was then separated into four parts: the anterior horn lying anterior to the vertical plane passed through the foramen of Monro; the body lying between this plane and one passed vertically through the ventricle tangent to the posterior relation of the thalamus; the posterior horn lying posterior to the latter plane, and the inferior horn lying anterior to it and below the body. The volume of each part was then carefully measured by the displacement of water in a graduate.

TABLE 1

Measurements in cubic centimeters of the volumes of the ventricles, with averages

CAST NO.	ANTERIOR HORN		BODY		POSTERIOR HORN		INFERIOR HORN	
	Left	Right	Left	Right	Left	Rig. t	Left	Right
1	3.5	3.9	3.2	3.3	3.6	4.1	0.4	0.5
2	8.2	7.3	9.8	7.5	22.1	10.0	2.2	0.8
3	5.7	4.4	3.4	4.1	5.0	5.2	0.5	0.5
4	3.2	2.9	8.2	10.0	9.3	10.0	0.5	0.5
5	5.5	4.3	7.5	5.2	5.9	7.7	1.5	2.1
6	1.2	1.0	2.1	2.3	1.6	1.0	0.2	0.4
7	0.6	0.5	1.0	0.7	1.3	1.1	0.6	0.5
8	7.2	7.4	8.2	7.9	4.8	4.5	0.7	0.5
9	1.0	2.0	1.3	1.8	1.2	1.4	0.5	0.6
10	2.4	1.7	1.1	1.1	4.0	2.9	0.6	0.3
Average	3.85	3.54	4.58	4.39	5.88	4.79	0.77	0.67

Table 1 gives the measurements of the volumes of the different parts and the average measurements of the ten casts. It is to be noted that the average volumes of the left ventricle exceed those of the right in each of the parts. The left anterior horn exceeds the right in seven of the casts, while the body, posterior horn, and inferior horn, although giving greater average volumes for the left side, show excess for either side in about an equal number of cases. Table 2 records the volumes of the ventricles and the corresponding brain-weights, together with the averages for the ten cases. Analysis of the figures comparing ventricular-

TABLE 2

Measurements in cubic centimeters of the volumes of the ventricles, and the weights in grams of the corresponding brains, with averages

CAST NO.	VOLUMES OF VENTRICLES					WEIGHT OF INCEPHALON
	Left	Right	Third	Fourth	Total	
						gms.
1	10.7	11.8	1.0	0.9	24.4	1332
2	42.3	25.6	2.0	0.8	70.7	1299
3	14.6	14.2	1.0	1.5	31.3	1619
4	21.2	23.4	....	0.8	45.4	1257
5	20.4	20.3	....	0.7	41.4	982
6	5.1	4.7	1.4	1.0	12.2	1413
7	3.5	2.8	0.7	0.9	8.9	1272
8	20.9	20.3	1.8	0.6	43.6	1212
9	4.0	5.8	0.7	0.8	11.3	1318
10	8.1	6.0	0.7	....	14.8	1431
Average	15.08	13.49	1.16	0.9	30.4	1314

volume with brain-weight shows an interesting relationship between the two: If the brain-weights be divided into two groups, those above the average weight and those below, it is seen that the average volume of the ventricles corresponding to the heavier group of brain-weights is much less than the average volume corresponding to the lighter group. The average volume of the ventricles corresponding to the brains weighing more than 1314 grams is 17 cc., while the average volume corresponding to brains less than 1314 grams in weight is 40 cc. In other words, for this series of casts and brains the volume of the ventricle varies inversely as the brain-weight.

The weights of the hemicerebrums are not included in table 2 because, owing to the somewhat mutilated condition of the brains after the removal of the casts, it was deemed best for the sake of experimental accuracy not to do so. Donaldson[2] shows that the weights of the hemicerebrums obtained by different observers are opposed, and suggests that no results are important unless it is

[2] Donaldson, H. H., The growth of the brain, pp. 184–185.

known by what method the division of the brain, was made. Broca[3] observed that the right hemisphere showed excess in weight over the left, but this excess was due to the greater weight of the parietal, temporal, and occipital lobes of the right side. For a comparison of the two frontal lobes shows that the left side exceeds the right. This difference is too slight, it has been suggested,[4] to be considered as a definite result, since it might well be accounted for in the error committed in dividing the frontal lobe from the remaining portion of the hemicerebrum. In other words, the weights of the hemicerebrums thus far obtained show so little difference between the sides that the suggestion of asymmetry is hardly possible.

Asymmetry of the anterior horns of the ventricles is definitely shown in this series of cases. It has been found in this examination of ten brains that the anterior horn of the left lateral ventricle exceeds the right in volume in seven cases: these taken in conjunction with the five cases previously examined indicating a constant tendency towards an excess volume of the left side. That for this series the volumes of the ventricles vary inversely with the brain-weights is shown by a comparison of the two series of measurements. The average total volume of the ventricles is greater than that of the Welcker cast (26 cc.)[5], begin 30.4 cc., so that the average volume of the cerebro-spinal fluid filling the ventricles is about 30.5 cc. It should be added that for this investigation no data were available giving the age and cause of death, and therefore the increase in the size of the cavities due to atrophy and shrinkage of nervous tissues cannot be considered. The presumptive age may be taken between the ages 40–70 years.

[3] Testut, Traite d'anatomie humaine, vol. 2, p. 611.
[4] Poirier, Traite d'anatomie humaine, vol. 3, p. 744.
[5] Donaldson, ibid., p. 87.

ON THE TEACHING OF ANATOMY

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The writer of this article has from time to time (while discussing the methods of teaching anatomy with anatomists) taken occasion to speak critically of the methods in general use. At their suggestion the views expressed are here given.

The study of anatomy was originally identified with the search for the nature of life. One can understand that the first attempts towards the unravelling of the mechanism of life should have been directed to an investigation of the organs of the human body and their functions. The desire for the understanding of the functions and not the desire for morphological description was uppermost in the minds of the older anatomists. This condition lasted until the middle of the nineteenth century. Even at that time the anatomists were primarily physiologists. Johannes Müller still wrote a text book of physiology; Henle wrote fascinating articles and books on physiological topics; the Webers, who taught anatomy made discoveries of fundamental importance in physiology and even Helmholtz was at one time, if I am not mistaken, a teacher of anatomy. Anatomy at that period was a thrilling topic full of vital interest, since it was devoted to the understanding of the functions of the human body and the nature of disease. An example of the text books of the premorphological period of Anatomy is Charles Bell's, "The Anatomy and Physiology of the Human Body."

The change in the character of anatomy came in Germany with the death of Johannes Müller—but was prepared within his lifetime. According to the biography of Johannes Müller, written by Du Bois-Reymond, Johannes Müller's dominating ambition seems to have been to become the German Cuvier. His produc-

tivity in purely descriptive morphology was enormous. Du Bois-Reymond states that on the average for a number of years Johannes Müller published over forty-eight pages of descriptive morphology not including the plates. There is a law of mass action in the development of the sciences as well as in chemical reactions and if a man as influential and famous as Johannes Müller pours out such quantities of purely descriptive material into the biological flask, it must determine the character of the product. The product was, at the death of Johannes Müller, a neat division of his chair into one for purely descriptive morphology—anatomy—and one for purely experimental science—physiology.

Was the result ideal or desirable? The writer doubts it. Anatomy is a real science if it contributes to the solution of the riddle of life or if it arouses in the student a desire to look for a solution of this riddle. The purely descriptive and technical way of teaching anatomy which is in use today cannot and does not arouse such such a desire in the student. If the writer is creditably informed there are offered at the present time courses in osteology lasting for sixteen weeks, consisting, in addition to regular lectures and quizzes, of two or three afternoons a week of 'laboratory work' in osteology devoted to th modeling of bones in clay. These efforts are often preceded by a 'grinding' course of equal length in descriptive embryology. The scientific interest left in the students after such courses are completed, could certainly no longer be directed towards the ideal of a search for the nature of life.

These things are not said with the purpose of critizing individual teachers; the anatomists of this generation find an established tradition of a purely morphological way of presenting Anatomy instead of presenting it in a physiological way. Would it not be natural for the anatomist to give the mechanism of the heartbeat in connection with the anatomical description of this organ; or to discuss the neurogenic theory of the heartbeat and the experiments which prove it, when he describes the ganglia of the heart? Would it not be natural to connect the experimental investigation of the functions of the spinal cord and the brain with the anatomical description of these organs? As a matter of fact most of these experiments, especially those on localiza-

tion are in reality of a purely anatomical character since they merely show the path of fibres. Would it not be natural for the anatomist to discuss the essential experiments on secretion or give the results of the experiments on internal secretion in connection with the description of the organs and their work? In this way its original character of a real science would be restored to anatomy instead of its continuing as a purely technical study.

A reaction against this latter condition of anatomy has already begun, in this country especially under the leadership of Mall.[1] Mall, himself is a pupil, not only of His, but also of Ludwig, and almost every one of his assistants and followers have entered the field of experimental embryology or biology. On the other hand, courses in osteology have disappeared from the curriculum of anatomy in Baltimore. If I am not mistaken a return to the functional or physiological mode of teaching anatomy would exactly correspond to the ideals of Professor Mall.

The objection will be raised, what is to become of physiology if such a change is inaugurated? I think physiology could only benefit by it. The real subject of physiology is the dynamics of protoplasm or the constitution of living matter. If viewed in this light the physiological laboratories have been for some time in danger of becoming sterile. Enzyme physiology, the phenomena of immunity, the experimental study of heredity, of fertilization, etc., have either been investigated outside of the laboratories of animal physiology or if they have been studied in a physiological laboratory, such work has been condemned as unphysiological, not only by the practitioners of medicine but by the so-called medical physiologists themselves. What to-day is called medical physiology proper, is in reality mostly anatomical physiology and should be taught by properly trained anatomists. If this were done, the physiological laboratory could again take its place in the vanguard of science as it once did in the days of Schwann, Pasteur, Ernest Heinrich Weber and Helmholtz.

[1] In Germany the opposition is led especially by Roux in Halle and his followers.

A FORMULA FOR DETERMINING THE TOTAL LENGTH OF THE LEOPARD FROG (R. PIPIENS) FOR A GIVEN BODY WEIGHT

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ONE FIGURE

In connection with a forthcoming paper on the seasonal variation in the weights of the central nervous system of the leopard frog (R. pipiens) Professor Donaldson asked me to fit the data on the total lengths for given body weights with a smooth continuous curve. The frogs used for this study were taken from the neighborhood of Chicago and from southern Minnesota. After several trials, the formula for such a curve was obtained and this has proved very satisfactory.

The formula is as follows:

$$y = 158 \log (x + 6.5) - 63$$

where y represents the total length in millimeters and x the body weight in grams.

The total length is the distance from the tip of the nose to the end of the longest toe, the frog being fully extended.

The body length is the distance from the tip of the nose to the tip of the urostyle and is 37.5 per cent of the total length. The body weight is given without ova in the case of the females and corrected for stomach contents when necessary.

If one wishes to compute the body weight for a given total length, this can be accomplished at once with the same formula by rearranging the variables. The expression then becomes as follows:

$$x = 10^{0.00633\,(y + 63)} - 6.5$$

Although the formula is purely empirical, nevertheless it is useful for the exclusion of swollen or emaciated frogs from any series and also

for determining any variations in the weight-length relations in specimens from different stations or of different species.

The formula is based on specimens of R. pipiens from Chicago and southern Minnesota. It may be used for frogs weighing as little as 3.5 grams, and has been extended to those as heavy as 75 grams, though this is not necessarily the upper limit of its application.

This range of application in body weight is indicated as follows:

$$3.5 \leq x \leq 75 \text{ grams}$$

Calculations of the total length for body weights increasing by five gram increments are given below.

Body Weight	Length Calculated	Body Weight	Length Calculated	Body Weight	Length Calculated
gms.	*mm.*	*gms.*	*mm.*	*gms.*	*mm.*
5	104.6	30	183.8	55	219.6
10	129.3	35	192.6	60	225.0
15	147.5	40	200.5	65	230.0
20	161.9	45	207.6	70	234.6
25	173.7	50	213.8	75	239.0

As an illustration of the use of this formula for determining variations according to the station, we find that the specimens of R. pipiens from the Brandywine Creek near Philadelphia are 4.4. per cent shorter than those from Chicago and southern Minnesota (Donaldson '11). Also on comparing the two European species (Donaldson '10) R. esculenta taken at Zurich, Switzerland and R. temporaria taken at Liverpool, England, with this standard for R. pipiens, it appears that R. esculenta is 5.1 per cent shorter and R. temporaria 3.5 per cent shorter. These species are in this character therefore more like the specimens of R. pipiens from the Brandywine Creek. In a case of this nature the choice of the material which is to be used for the standard formula is quite arbitrary. To indicate how the formula can be modified to suit other material let us assume that we desired to use the Brandywine frogs, which are 4.4. per cent shorter than the Chicago and Minnesota frogs, as the material for a standard formula.

The desired formula can be derived from the one given above in the following manner:

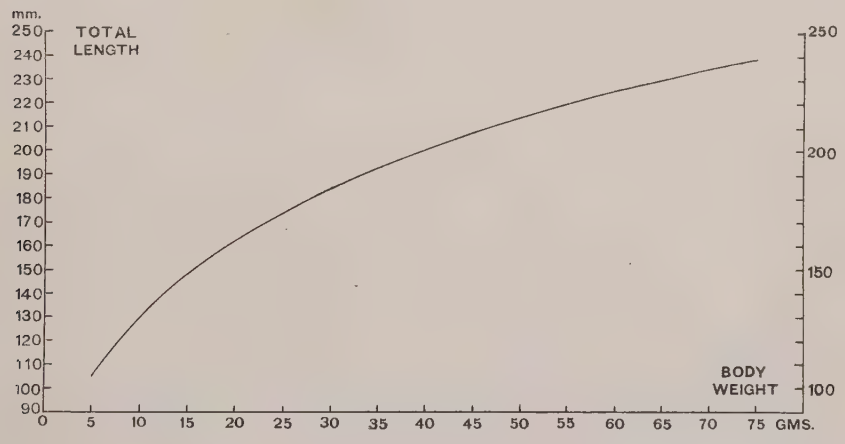
$$y = [158 \log (x + 6.5) - 63] - 0.044 [158 \log (x + 6.5) - 63]$$

that is, the new formula is obtained by reducing the two constants (158 and 63) by 4.4 per cent. It would then become:

$$y = 151.048 \log (x + 6.5) - 60.228$$

which represent the weight-length relations for the Brandywine frogs. By a similar process, corresponding formulas could be obtained for the two European species.

The graph of the formula for the total length at different values of the body weight is illustrated in the accompanying chart.



On the base line representing the body weight of the leopard frog (R. pipiens) given in grams, the ordinates show the total lengths in millimeters. The curve for these determinations of total lengths is given for frogs from 5 to 75 grams in weight.

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THE HISTOLOGICAL DEMONSTRATION OF LIPOIDS

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In connection with work on the interstitial cells of the ovary and the cortex of the suprarenal gland, I had occasion to carry out some experiments on the technique of fat demonstration and preservation and, as they supplement largely the careful observations of Bell[1] published in this Journal, it occurred to me that the results although not extensive or peculiarly original might nevertheless be of interest to other workers, who might in turn offer suggestions from their experience. The satisfactory preservation of lipoids is difficult for obvious reasons and is a neglected side of cytological work that will soon require more attention if we may judge by the suggestions of their importance that have been made in the field of cell physiology (lecithin in relation to nuclein synthesis, and *vice versa;* the form in which lipoids exist in the cytoplasm, masked fat, etc.; Overton's and Loeb's work). The usual cell picture generally neglects them and is clearly inadequate. The histological technique of lipoids is rendered more difficult by the fact that they exist in intimate mixtures and the probability might be suggested that the more intimate the 'mixture' the greater their importance in protoplasm.

The fat globules of the suprarenal and ovary are unusually labile as compared with 'body fats' (adipose tissue), as is of course well recognized,—this aside apparently from the difference in size of the globules. The nature of the suprarenal fat does not seem to have been sufficiently determined. Doubly refracting 'myelin' globules are present but the chemical composition of these is in dispute. It has been analyzed recently (*e.g.*, by White[2]) as cholesterin and oleic acid in physical or chemical combination. In the interstitial cells of the ovary no analysis has as far as I know been made. I have so far failed to secure evidence of the existence of the double refraction indicative of myelin (cholesterin and oleic acid); in all probability the granules are largely oleic acid. Doubtless many of the intracellular fat globules are of this character and cer-

[1] Bell, E. T.: The Anat. Record, vol. 4, no. 5, 1910.

[2] White, Chas. P.: The Journ. Pathol. and Bacteriol. vol. 13, pp. 11–13. 1908.

tainly much of the fat appearing under pathological conditions (*vide* Adami; principles of pathology).

Bell has pointed out that the group of selective fat dyes which owe their staining value to their solubility in fats,—Sudan III, Scharlach R., Indophenol, etc., give the most definite and delicate reaction for fat. He finds Herxheimer's alkaline (alcoholic) stain most efficient. The necessity of using the freezing microtome and mounting in glycerin or glycerin jelly renders them less serviceable for use in cases in which it is desirable to study the cell structure as well or employ serial sectioning. Personally I have employed them merely as a control,—counter-check to other methods. Since they color indiscriminately all free lipoids, including lecithin, cholesterin, and myeline, they afford no analysis of the lipoids present.

Osmic acid (osmium tetroxid). This well known reagent for the demonstration of fat usually requires little precaution to ensure satisfactory results;—the employment of thin pieces of tissue (1 mm.), the avoidance of absolute alcohol, the use of thick cedarwood oil or chloroform as a clearer before paraffin imbedding. With easily soluble fats such as those in the suprarenal and ovary, however, it is necessary to employ further precautions. I found carbol-xylene (1:3) or chloroform as a clearer before the paraffin gave best results but there was nevertheless usually more or less solution of the 'osmicated' fat particularly in the less superficial tissue, and it was different in different specimens. The reason for this difference is not quite clear. It is not due to absolute lack of penetration since the fat was blackened, though it seems to be associated with a less perfect oxidation of the fat. Duration of fixation or period of time in the alcohols had no appreciable effect. Celloidin, however, was found to be the best imbedding material and by employing 95% alcohol instead of absolute alcohol in making up the solutions, the blackened fat granules may be retained quite perfectly. It was found necessary however to mount without a coverglass as with chrome-silver impregnation preparations or employ very thick balsam. After the solvent of the balsam has largely dried out, it may be melted by heat and a coverglass added. Safranin was employed as a stain which will retain its brilliancy for sometime without a coverglass.

Tests carried out at my suggestion in the laboratory indicate that this is the best technique for permancy in the application of the Marchi method, depending as it does on the preservation (in situ) of osmicated fat granules (probably oleic acid?).

Chloroform or benzene balsam had no advantages as a mounting medium as compared with xylene balsam or natural balsam.

By the employment of celloidin and observing the above mentioned precautions in mounting, even small granules of fat that blacken with osmic acid may be preserved.

Altmann[3] and Starcke[4] have shown that it is only the unsaturated fats and fatty acids (such as oleic acid) which are able to reduce the osmium tetroxid, upon which reduction the staining reaction depends. Starcke added the significant point that in the case of the saturated fats (*e. g.* palmatin and stearin) blackening subsequently appears if the tissue is immersed in alcohol. A satisfactory explanation of this has not been vouchsafed. The two groups may of course be distinguished by making examination by the freezing microtome or otherwise without submitting the tissue to the action of alcohol and the presence of unsaturated fats determined (as in case the of the ovary and suprarenal). Since the reaction depends on the presence of a reduction of the osmium tetroxid it must of course be borne in mind that there are other reducing substances in the body in addition to the unsaturated fats, and R. Heidenhain's dictum that "all that blackens is not fat" be given due consideration.

That cytoplasm usually blackens to a certain degree is a matter of general observation. This is due to the presence of reducing substance in the protoplasm, whether masked lipoid cannot be said at present.

The reducing power of fatty-acid-containing complexes such as 'myelin' may be markedly different from that of the fatty acid alone. Thus it is a common laboratory observation that myelin blackens readily and intensely with osmic acid used alone or as in Hermann's fluid but when conbined with other oxidizing substances such as chromic acid (as in Flemming's fluid) the myelin blackens little or not at all. The histological analysis of intracellular fats may often be facilitated in this way; thus it becomes doubtful if Smith and Mair (vid. seq.) are correct in their argument that the oleic acid in myelin is in the form of loose combination with the cholesterin since (granting the correctness of the determination) the cholesterin oleic acid combination in the suprerenal cortex stains readily with osmium tetroxid in the presence of chromic acid. If not chemical, at least the physical conditions of the combination are markedly different. Fixation in Flemming's fluid for differentiating free fat from myelin has been used instead of the Marchi method with marked success in the case of small brains and peripheral nerves (*e.g.*, Myers[5]).

[3] Altmann, R.: Die Elementarorganismen. Leipzig, 1894.

[4] Starke, J.: Arch. f. Physiol. 1895.

[5] Myers, B. D.: Zeitschr. f. Morphol. and Anthropol. Bd. 3, pp. 183–207, 1900.

The Weigert method. The use of the Weigert hematoxylin method for other purposes than the staining of myelinic sheaths has already been described by Schiefferdecker who employed it as a stain for skin, lymphatic tissue and blood; by Harvey[6] as a stain for zymogen granules, etc. It has also been used for the specific staining of fats and fatty acids (Fischler,[7] Benda[8]).

Smith and Mair[9] have recently published experiments on the chemistry of the Weigert method of staining medullated nerves which are of considerable interest to the histologist. The conclusion reached by them was that the mordantage by means of the dichromate on which the stain depends was determined by the ability of the myelin to reduce the potassium dichromate to the trioxid (?) held in combination in the myelin. The unsaturated fatty acids and their fats (*e.g.*, oleic acid and olein) were able to reduce the dichromates and stained in the hematoxylin; the saturated fats and fatty acids (*e.g.*, stearin and palmatin) gave negative results as did also pure cholesterin. Impure and combined cholesterin, however gave positive results even if combined with a saturated fat. Commercial lecithin (Kahlbaum's) stained, but purification rendered it less easily stained. The authors are inclined therefore to believe that pure lecithin like cholesterin would give negative results; that it is not the lecithin in myelin but a cholesterin-oleic acid combination which reduces the dichromate. While keeping in mind the questionableness of the last conclusion and the possibility that physical factors (fluidity, etc.) may be of fundamental importance in the reaction, there would seem to be no doubt as to the correctness of the main result,—that the Wiegert hematoxylin method rests upon the same basis as the osmic acid method,—namely, the presence of reducing substances. Alcohols were also found by them to stain. It would have been an interesting point to have ascertained whether as is the case with osmic acid according to Starcke's results the saturated fats might not have stained after treatment with ethyl alcohol.

A second study of the microchemical and staining reactions of lipoids of importance to the morphologist is one by Faure-Fremiet, Mayer and Schaeffer.[10] In this they not only present many chemical facts in explana-

[6] Harvey, B. C. H.: Amer. Journ. of Anat. vol. 6, pp. 207–243. 1906.

[7] Fischler: Centralbl. Allg. Pathol. Bd. 15, 1904.

[8] Benda: Arch. f. pathol. Anat., Bd. 161, 1900.

[9] Smith, J. L., Mair, W., and Thorpe, J. F.: The Journ. Pathol. and Bacteriol. vol. 13, pp. 14–27, 1908–1909.

[10] Fauré-Fremiet, E., Mayer, A, and Schaeffer G. Arch. d'Anat. Microscopique. vol. 12, pp. 19–102, 1910.

tion of the fixation and staining of fats, myelin, etc., but deal as well with the chemical nature of the mitochondria, and offer a suggestion as to the basis of the chrome-silver reaction. Their main results are gathered together in the form of a table (7, p. 80). Their work supports that of Smith and Mair but is more comprehensive in its scope, not being limited to the Weigert hematoxylin method. They seem to find however that osmic and chromic acid oxidize the saturated fats, but with difficulty.

I found that theWeigert method gave very useful results with the lipoid containing cells of the ovary and suprarenal. The procedure that was found most satisfactory was to fix two days in Zenker's fluid following it up by a mordantage in Muller's fluid for 10–14 days at 38°C (in an incubator). A longer stay in dichromate solutions in the cold did not seem as satisfactory even though prolonged (one month or more). The paraffin imbedding method was employed, iodine in the alcohol being used to remove any precipitate that might be present. The sections were stained on the slide by the 1885 Weigert hematoxylin method which seemed preferable to the Pal-Weigert method which was also tried. The preliminary fixation by means of the Zenker's fluid prevented the partial solution of the chromatin and loss of nuclear structure which the potassium dichromate would otherwise have caused. The combination of the dichromate with mercuric chlorid and acetic aid was found to give better results than the mixture of potassium dichromate and formalin (Orth's fluid) or a mixture of dichromate, mercuric chlorid and formaldehyde such as Helly's fluid, a small amount of acid seeming to facilitate the mordantage and sharpen the differential staining. Usually the amount of acetic acid in the Zenker's fluid was reduced to 1 percent. In the differentiation by means of the potassium ferricyanide and borax bleacher, the solution was diluted 3–4 times and permitted to act more slowly. Iron hematoxylin methods were used as well as copper hematoxylin methods but did not give, it seemed to me, as sharp a differentiation.

Peripheral myelinic nerve fibers, the fat containing cells and erythrocytes were sharply differentiated. The lutein cells of corpora lutea are strongly stained. Mitochondria are preserved and intensely stained, though not quite as well apparently as by the Benda method or Meves modification. In the case of the four first mentioned, the selective stain is undoubtedly associated with the presence of the lipoid, and since the evidence is fairly strong that the so-called mitochondria or chondriosomes possess a lipoid element in their composition (10), their preservation and staining may be explained on the same basis. The above technique is, in fact, essentially mitochondrial, and by using a minimal

amount of acetic acid ($\frac{1}{2}$– 1 per cent) gives usually good results. The Benda method of fixation, while it affords a sharper and a stronger stain of the mitochondria, gives generally inferior results with the cells containing free fat, the treatment with the pyroligneous acid being apparently largely responsible. Benda's fluid (modification of Flemming's fluid) employed by itself gives an excellent osmic acid stain of free fat and (after bleaching with hydrogen peroxid) admits good staining of the mitochondria. The copper hematoxylin gives a richer and more differential stain for mitochondria than does the iron hematoxylin more frequently employed for this purpose.

The intracellular globules of free lipoid themselves were not individually preserved by this technique and the intense staining was peripheral, either marking out a distinct surface layer of the globule or staining the interstitial cytoplasm often revealing an apparent granular structure (mitochondria?). The interpretations of this might be (*a*) that the reduction upon which the staining reaction depends took place only at the surface of the globule and the bulk of the globule being subsequently dissolved out. One need but recall the surface staining of fat globules with osmic acid and the 'Ringkörper' of Altmann. (*b*) That the reaction took place in a surface layer of 'formative substance' in which the fat was possibly held in combination (masked form) as in the mitochondria. (*c*) That the lipoid from the globule in the process of fixation had permeated the surrounding cytoplasm.

For the differential staining of the individual fat granules and glubules by the Weigert method, it is apparently necessary to resort to the use of the freezing microtome as Benda and Fischler have done who have stained the fatty acid by means of the Weigert method and the neutral fat with Sudan III. It is possible however that further experimentation will determine a mordantage that followed by celloidin imbedding will permit of the preservation and staining of the individual fat granule. Despite the existing imperfection, however, the method was found to be very useful in the case of the ovary and suprarenal gland.

It might be mentioned that by fixing small heads, such as those of many teleosts, for three or four days in Zenker's fluid and following this by a dichromate mordantage in Muller's fluid of two or three weeks, (shortened by heat if preferred), an excellent Weigert hematoxylin stain of the peripheral nerves may be secured, the acetic acid and dichromate together affording a sufficient decalcification without marked injury of the myelinic sheath. Such material is not as brittle as that secured by long fixation in Flemming's fluid.

REGARDING THE PRESERVATION OF ANATOMICAL MATERIAL

GEORGE L. STREETER

From the Anatomical Laboratory of the University of Michigan

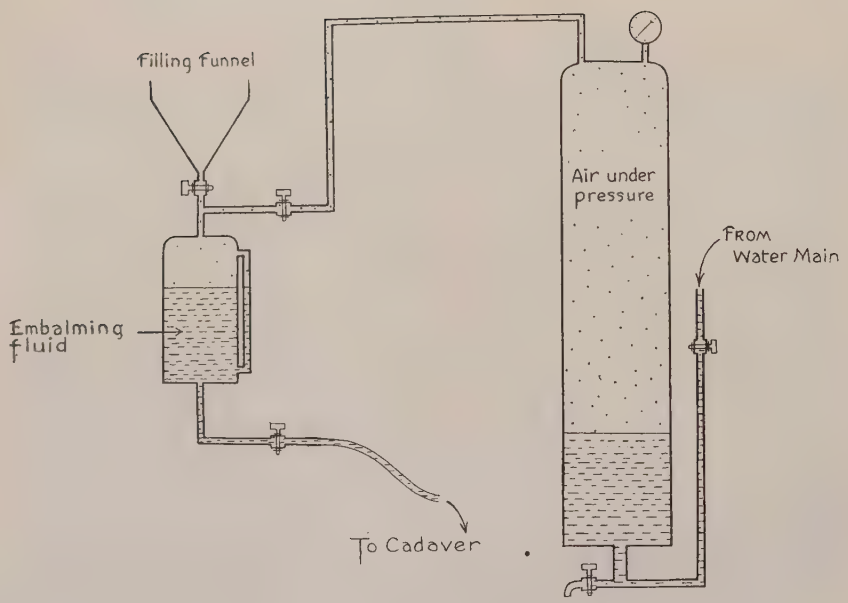
TWO FIGURES

The importance of the provision of properly embalmed dissection material is a matter that should not be lost sight of by anyone who assumes the responsibility of teaching students gross anatomy. The character of the dissection material together with a well lighted and well arranged dissection room are about the only factors for which the student is clearly dependent upon the teacher. Any deficiency in these two requisites cannot be compensated for by ability or earnestness, either on the part of the student or of the teacher.

At Ann Arbor we have kept this constantly in mind and have made a steady endeavor to perfect our method, in every way possible, with the view toward providing the students with material best fitted for dissection. With one change we have made we are so well pleased, that I am writing this note thinking it may be of use in other laboratories.

In our laboratory we are all convinced that satisfactory preservation is dependent upon the thorough saturation of the tissues with the embalming fluid. We make it a practice in fact to saturate the tissues to the point of oedema, so that the areas which are not directly reached through the vascular system, will receive the preservative subsequently by diffusion through the tissues. This is particularly important with us, as a large percentage of our bodies are of elderly individuals with sclerotic arteries and frequent thromboses. As a rule we inject from 20 to 30 quarts of preservative (formalin, 6 per cent, carbolic acid 4 per cent, and glycerine, 20 per cent).

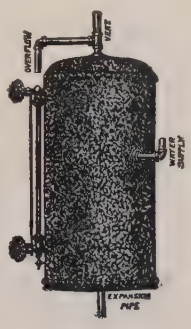
The injection of a large amount of fluid requires a good apparatus. Previously we had always worked with a glass container (percolator or large glass bottle), supposing it to be necessary with solutions containing such fluids as formalin or carbolic acid. With the use of glass,


Filling Funnel
Air under pressure
From Water Main
Embalming fluid
To Cadaver

1

however, we were always troubled with leaky joints, and as we have to embalm about 100 bodies a year, our defective apparatus was a constant source of annoyance to us. It meant in each case that some member of the staff would have to go to the aid of the janitor. We plainly faced the problem of designing a fool-proof injection apparatus which an ordinary janitor could use. It was this that led us to try what is practically an all-metal apparatus. We have had it in successful operation about two years, and as yet it shows no sign of corrosion or other defect. With it we are able to force into our cadavers a large amount of fluid under any desired pressure, and carried over any length of time.

As can be seen by fig. 1, the apparatus consists of an air-compressor, connected by a $\frac{1}{2}$-inch pipe with an injection tank. The air compressor is arranged in the ordinary manner for securing an air pressure. It



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consists of a 30-gallon galvanized iron reservoir into which water enters from below, compressing the air above it, the pressure in pounds being registered by a gauge at the top of the reservoir.

The injecting tank, (see fig. 2) consists of a $5\frac{1}{2}$-gallon galvanized iron cylinder, commercially known as an *expansion tank*[1]. A large receiving funnel is mounted above it. Ten quarts of fluid can be poured at one time into the funnel, from where, by a valve, it is let down into the injecting tank below, the amount of fluid in the tank being shown by the gauge on the side. A pipe leads from the bottom of the tank to the edge of the shelf on which the tank is mounted, at a convenient place

[1]This expansion tank as it appears in the trade is shown in fig. 2, the cut for which was kindly loaned by James B. Clow and Sons, Chicago, from whom the tank together with gauge may be obtained for about $6.00.

for attaching the rubber tube leading to the cadaver. The necessary valves are indicated in fig. 1, and their purpose is so evident it need not be detailed.

As was mentioned, our apparatus has already been in operation about two years, and the only attention it has required has been the occasional replacement of the short rubber tube leading fron the discharge pipe to the cadaver. It is the conviction of the writer that those who believe in a thorough saturation of the tissues with embalming fluid will find an apparatus of this character convenient and effective.

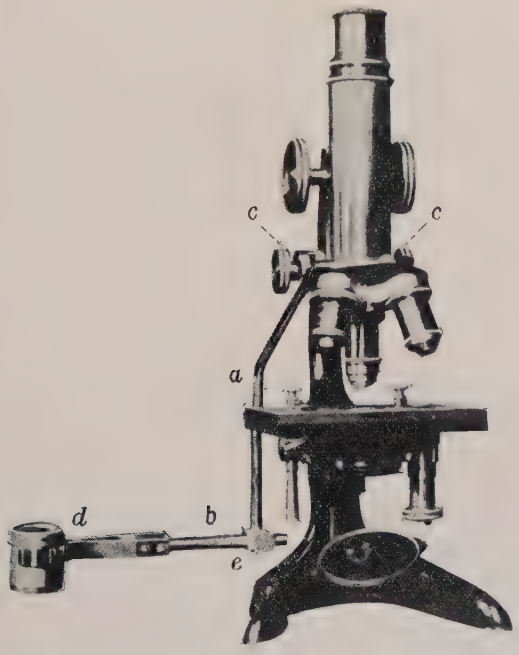
A DISSECTING MICROSCOPE, AN ACCESSORY OF THE COMPOUND MICROSCOPE

VICTOR E. EMMEL

From the Department of Anatomy, Washington University

ONE FIGURE

The dissecting microscope[1] represented in the accompanying figure was designed for the class laboratory, where the amount of space allotted



to the individual student for working room and apparatus is an important consideration. The instrument, consisting of a light metal support hold-

[1] This accessory microscope is made by the Spencer Lens Co., of Buffalo, N. Y.

ing the lens, is attached to a compound microscope, the latter thus furnishing a stand and focusing mechanism.

The support is composed of two parts: an upright rod (*a*), and a horizontal lens-arm (*b*). One end of the upright rod is bent to fit about the body-tube of the compound microscope on which it is firmly fixed just above the nose-piece by means of three thumb-screws (*c*). It will be observed that the upright is set back of the stage and therefore offers no interference with the use of the compound microscope; when the dissecting microscope is adjusted either instrument can be manipulated without inconvenience. No modification of the compound microscope is necessary for attaching the accessory, and any of the stands, ordinarily found in our laboratories, can be used equally well. A spring clutch (*d*) holds the lens. Two joints (*e*), controlled by thumb-screws, permit the necessary adjustments of the lens-arm and lens to the the object and dissecting dish. Focusing is done by means of the coarse adjustment.

When the dissecting lens is not in use it may be swung under the stage, or the entire instrument may be disconnected. For class purposes, however, it is desirable to keep the accessory apparatus attached to the compound miscroscope so that there may be an instrument, available at any time, for either high or low power magnification. The combined instruments fit into the box made for the compound microscope, a convenience readily appreciated.

THE MICROSCOPIC ANATOMY OF THE EPIPHYSIS OF THE OPOSSUM

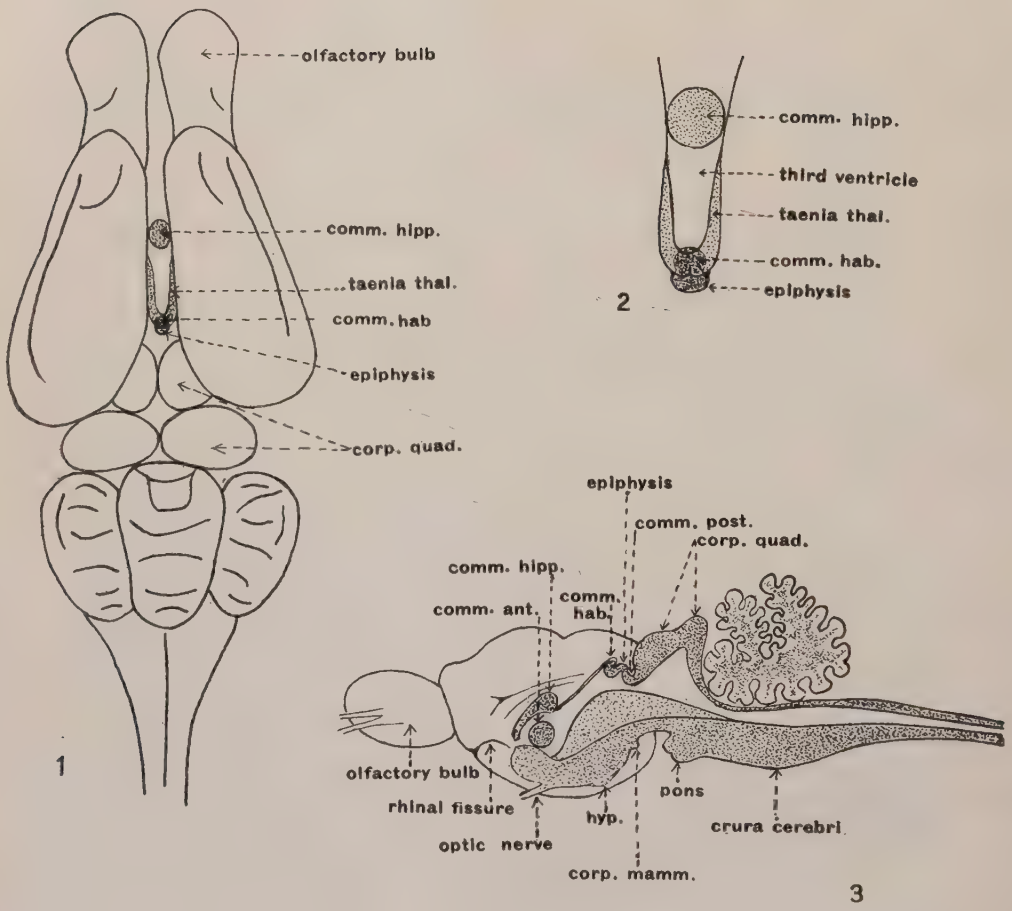
H. E. JORDAN

From the Anatomical Laboratory of the University of Virginia

EIGHTEEN FIGURES

Failure to identify macroscopically the epiphysis of the opossum, while engaged in a comparative study of the pineal body of various mammals, led to a careful search for this structure in sections of the epiphyseal region. The sections thus obtained form the basis of the histologic study the results of which are here recorded. The material used in this investigation comprises four gross preparations and four sets of serial sections, all of adult animals, five males and three females. The fixing fluids employed were 95 per cent alcohol, 10 per cent formaldehyde, and Müller-formol. Iron-haematoxylin was used principally for staining, combined also with a variety of counter-stains. The primary points of interest concern the morphologic variability of the epiphysis, its rudimentary condition and the presence of very coarse neuroglia fibers. The presence of tubules, a follicular arrangement of the parenchyma and the presence of nerve fibres is also deemed of sufficient importance to warrant careful description.

Macroscopically, on separating the cerebral hemispheres, the epiphysis can be seen as a slight bulbar evagination slightly below and immediately behind the habenular commissure (figs. 1 and 2). Median longitudinal sections of the brain (fig. 3), and of the habenular region (fig. 4), disclose more clearly its relation to the habenular and posterior commissures. It consists simply of an evagination of variable degree from the inter-commissural portion of the roof of the third ventricle. This simple shallow tubular structure indicates a morphologic and physiologic rudi-



EXPLANATION OF FIGURES

1 Sketch of surface view of opossum's brain showing the relation of the epiphysis to surrounding structures. × 2.

2 More highly magnified sketch of surface view of epiphyseal region. × 8.

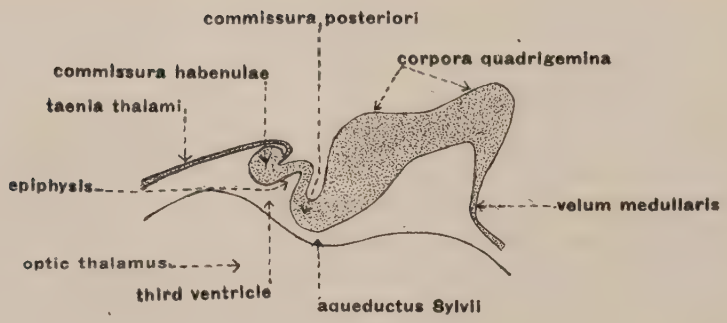
3 Sketch of median longitudinal section through brain showing the short type of epiphysis and its relation to the posterior and habenular (superior) commissures. × 2.

mentary condition. The adult form of the epiphysis of the opossum, therefore, recalls the embryonic form of this body in many vertebrates, and appears to represent a condition of primitive or of arrested development.

A variation characterized by considerable elongation, and in this case terminal invagination by a pial plug, giving rise to a bi-tubular apex, is illustrated in fig. 5. This represents one extreme of the structural variations as they appear in my specimens. The other extreme is illustrated in figs. 4 and 14. Fig. 8 represents an intermediate type of moderate elongation in the form of a simple tube.

The type of epiphysis illustrated in fig. 5 is connected to the posterior commissure by an ependymal pars intercalcaris ('Schaltstück') and extends backward over the inter-collicular furrow of the anterior corpora quadrigemina, closely attached to the latter by pia mater. The connection between epiphysis and habenular commissure is made through the medium of a sparser ependymal membrane, apparently interrupted in small areas near the habenular commissure. The epithelium (ependyma) covering the commissure internally is continuous with that of the epiphysis and its stalk (taeniae thalami of the pineal peduncles) and is similar in character throughout. In the epiphysis itself the epithelium consists of a number of layers, in the intercalated portion of two or three layers, in the stalk connecting the body with the habenular commissure of a single layer with lacunae, and over the commissure of many layers. The epiphysis is covered by the pia mater from which a few small blood vessels enter the epithelium. The only slight vascularity of the body itself is a conspicuous characteristic of the epiphysis of the opossum as compared with that of many higher mammals, as for instance the sheep. Being merely a comparatively thin membrane, however, the blood vessels of the closely investing pia mater would seem adequate to care for the nutrition and possible excretion of the specific cells. Delicate bundles of medullated nerve fibres are discernable throughout the entire inter-commissural portion of the epiphyseal region.

Fig. 6 illustrates the structural details of the epiphysis proper, here bifid terminally. The interesting features are the few small



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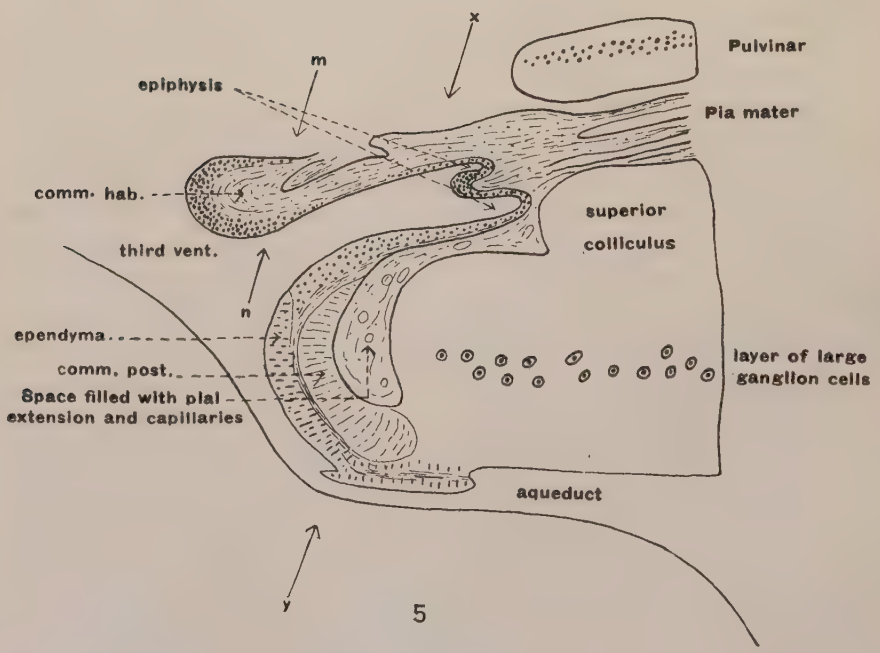

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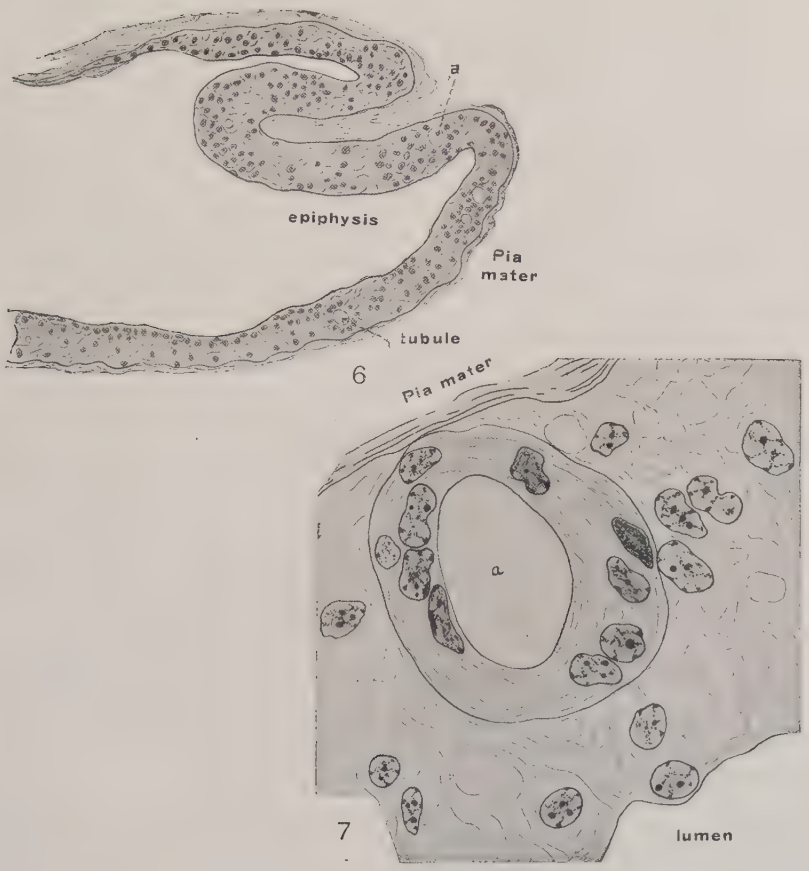
EXPLANATION OF FIGURES

4 More highly magnified sketch of the epiphyseal region of fig. 3. × 8.

5 Camera lucida sketch of an elongate tubular type of epiphysis, with related structures. This epiphysis is invaginated terminally by a pial plug. × 25.



EXPLANATION OF FIGURES

6 More highly magnified camera lucida sketch of this epiphysis showing the presence of several tubules. × 200.

7 Sketch of a single tubule (*a* of fig. 6) highly magnified. The surrounding tissue is syncytial in character, and contains neuroglia cells and fibers, and vacuoles. × 1500.

tubules or alveoli. These extend through from 4 to 6 sections of 10 micra thickness, and may branch. In no case could they be traced into the lumen of the epiphysis. They appear also in the epithelium of the habenular commissure. Their wall consists of more compact and densely nucleated protoplasm, syncytial

in character. It is uncertain whether these are actual tubules with distinct walls or simply tubular simulacra, due to the accumulation of a secretion and consequent peripheral pressure on the cells of the surrounding tissue. The latter condition would result in a structure like the 'tubules' here present, and closely simulate gland alveoli (fig. 7). Occasionally cell outlines can be seen among the cells of the tubule wall. This fact, combined with the presence of follicles of cells in the shorter epiphyses, renders it probable that the 'tubules' above described are actually blind secretory structures. On the contrary, the presence of numerous vacuoles (fig. 7) favors the alternative interpretation, *i.e.*, that they are cysts.

The epiphysis appears composed of a syncytial neuroglia framework in the meshes of which are scattered more or less highly differentiated or modified ependymal cells, and of delicate bundles of nerve fibres.

Cross sections of the somewhat shorter and simple type of epiphysis at several levels are illustrated in figs. 8, 9, and 13. The first is approximately at the level of x–y in fig. 5, and the last through the habenular commissure in approximately the plane of m – n, fig. 5. Fig. 9 is taken from a section 200 micra forward of fig. 8. The histologic structure of this epiphysis is similar to the former in respect to neuroglia, ependyma and nerve fibres (figs. 10 and 11). It lacks the 'tubules' above described; and the epithelial stalk connecting the body with the habenular commissure appears uninterrupted.

The more usual type of epiphysis in the opossum seems to be the one illustrated in figs. 4, 14 and 17. It is simply a shallow ependymal outpocketing behind and below the habenular commissure passing, without sharp line of demarcation, forward into the former and backward into the pars intercalaris connecting it to the posterior commissure (fig. 14). Centrally it is composed of a dense mass of cells; peripherally of similar cells arranged into follicles (figs. 15 and 18) with a framework of coarse neuroglia fibres, and separated one from the other by delicate bundles of nerve fibres. No tubules are present. Possibly the 'follicles' represent these structures of the elongate type of

epiphysis. The important histologic characteristics are 1, presence of nerve fibres peripherally placed and continuous with both commissures, and perhaps representative of the so-called pineal nerve of some forms; 2, presence of large irregular neuroglia cells (figs. 12, 15 and 16) and very coarse neuroglia fibres peripherally placed and forming the framework of the follicles (in neither of the commissures nor elsewhere are seen such coarse neuroglia fibres); 3, syncytial neuroglia framework, supporting less differentiated ependymal cell of spherical and polygonal shape, (figs. 11 and 15); 4, very few and delicate blood vessels; 5, bundles of medullated nerve fibres between the peripheral follicles. The lining epithelium of the epiphysis is similar to the investing epithelium of the habenular commissure. Structurally the latter is in all respects like the former, with, however, its two layers in the reverse order, except that it lacks the coarse neuroglia fibers and the follicular arrangement of its ependymal cells.

Figs. 11, 12 and 16, illustrate the several cell types and the neuroglia fibers. The neurologia fibres are of two main types, namely coarse and delicate; there are also fibers of intermediate grades. Many of the fibres of all grades of thickness are clearly in continuity with cell bodies. Others appear entirely separated from the cells proper, (figs. 12 and 16). The finer grades form the meshwork in the interstices of which the non-neuroglia cells are imbedded.

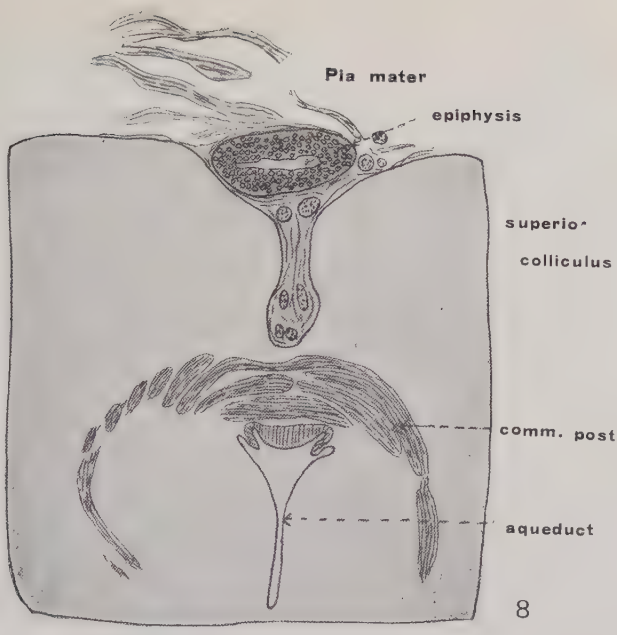
As regards staining reaction of the neuroglia fibers it is of interest to note that iron-haematoxylin seems specific for the coarser types, more especially after Müller-formol fixation; somewhat less definitely after simple formalin fixation. They stain intensely black; the finer fibres stain yellow, while those of intermediate grades stain with varying shades of brown.

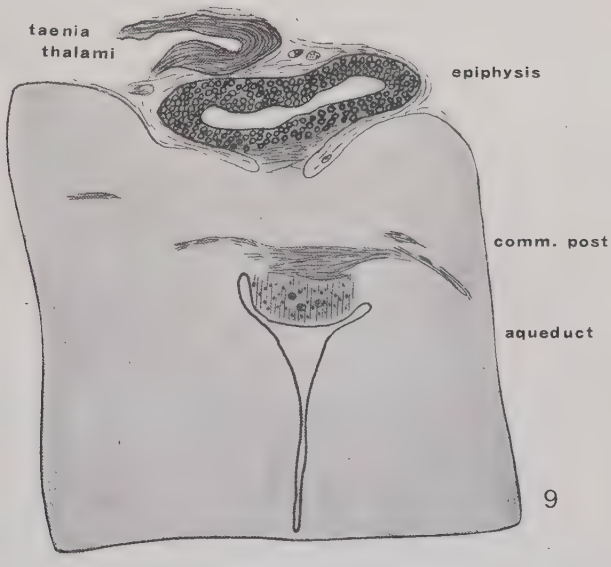
The neuroglia cells are irregularly polygonal or stellate in form and of varying sizes. The nuclei are vesicular; the cytoplasm finely reticular. A small number are of oval form with oval, chromatic nuclei, (fig. 15, below to left). The remaining cells are of spherical form or ovoid bodies with vesicular nuclei and reticular cytoplasm (fig. 11), and appear to fill the meshes of the neuroglia syncytium.

On the basis of the presence of various grades of apparent transition forms between the spherical parenchymal cells and the irregular neuroglia cells; and that of a general protoplasmic similarity, both cytologic and microchemical, the most reasonable assumption seems to be to regard all the above mentioned types of cells as different modifications or degrees of differentiation of the same type of ependymal cell.

The morphologic variability of the epiphysis of the opossum, combined with the simple histologic structure, marks it as a primitive or rudimentary organ. Measured by histologic criteria, its functional importance would seem to be wholly or nearly nil. In its adult form the tubular type appears on superficial examination to show resemblance to the epiphysis of selachii, (Acanthias, Minot, '10); teleosts, (Opsanus, Terry, '10), and tailed amphibia, (Necturus, Warren, '05). However, the homologues of four of the six morphologic divisions of the forebrain roof first recognized by Minot in the embryo of Acanthias, namely, paraphyseal arch, paraphysis; velum transversum; and post-velar arch, and identified by Terry in Opsanus and by Warren in Necturus, are not recognizable in the brain of the adult opossum. The short tubular or thick-walled cup-type corresponds closely to the embryonic form of vertebrates, more especially mammals, as for instance sheep; and somewhat also to the adult form of some of the more simplified types among mammals, as in the cat.

The epiphysis of the opossum thus appears to be in a condition of morphologic instability. From the veiwpoint of phylogeny, employing the character of the epiphysis as a mark for classification, the long tubular form of epiphysis connects the opossum with birds and reptiles; the short tubular or cup-type with lower mammals, more especially carnivora. If this interpretation is valid, and if the epiphysis may be regarded as an index of phylogenetic position, one would expect the epiphysis of monotremes to be a long tubular body. However, the few illustrations of monotreme brains, as that of ornithorhynchus—Elliot Smith, indicate that it is at least in some cases cup-shaped. That the form and structure of the epiphysis may serve as a guide in establishing phylogenetic relationships is further (*i. e.* besides the fact that marsu-

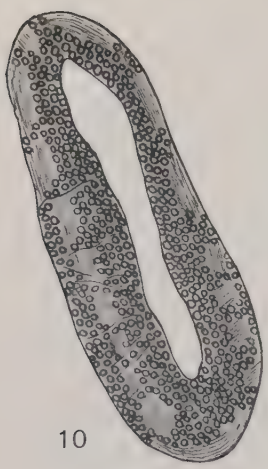


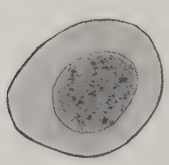


EXPLANATION OF FIGURES

8 Camera lucida sketch of transverse section of a less elongate simple tubular type of epiphysis. The section passes approximately through the plane x — y in figs. 5 and 14. × 25.

9 Section 200 microns forward of fig. 8. × 25.





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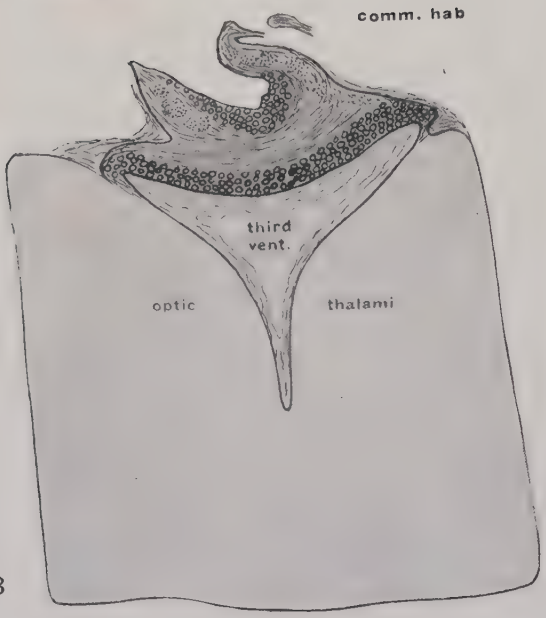

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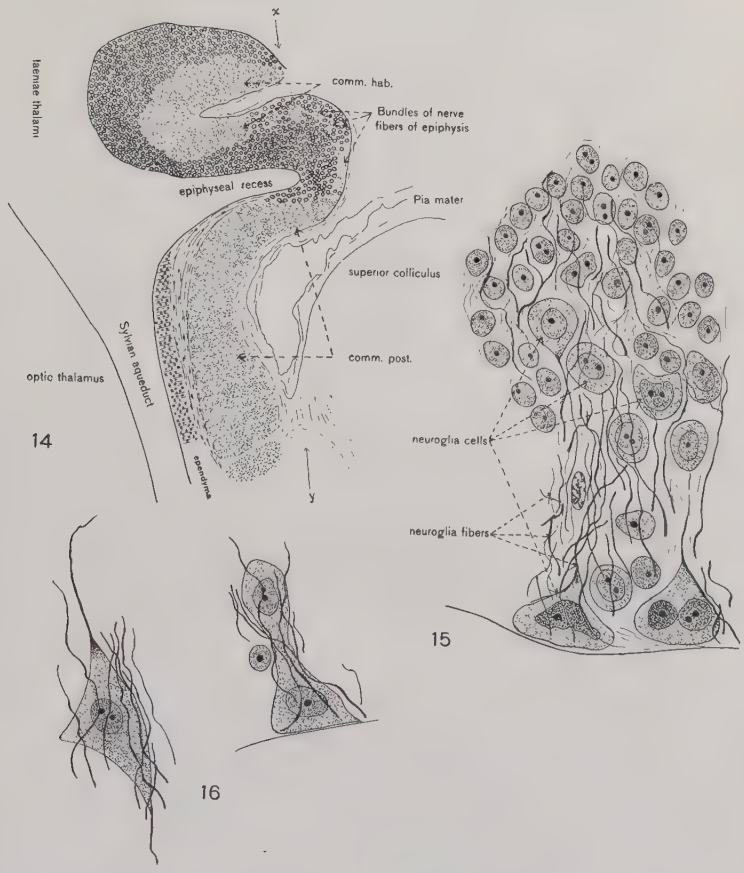
EXPLANATION OF FIGURES

10 Sketch of section of epiphysis of fig. 9, to show the distribution of the cells, coarse neuroglia fibers and bundles of white nerve fibers. × 50.

11 Sketch illustrating character of cells lying in the meshes of the neuroglia network. The nuclei are pale with scattered chromatic particles. The cytoplasm appears non-granular and finely reticular. × 1500.

12 Camera lucida sketch illustrating a typical neuroglia cell with fine and coarse fibers, from fig. 10. × 1500.

13 Section considerably farther forward than fig. 9, approximately through plane m — n of fig. 5, showing the character of the habenular commissure. × 25.

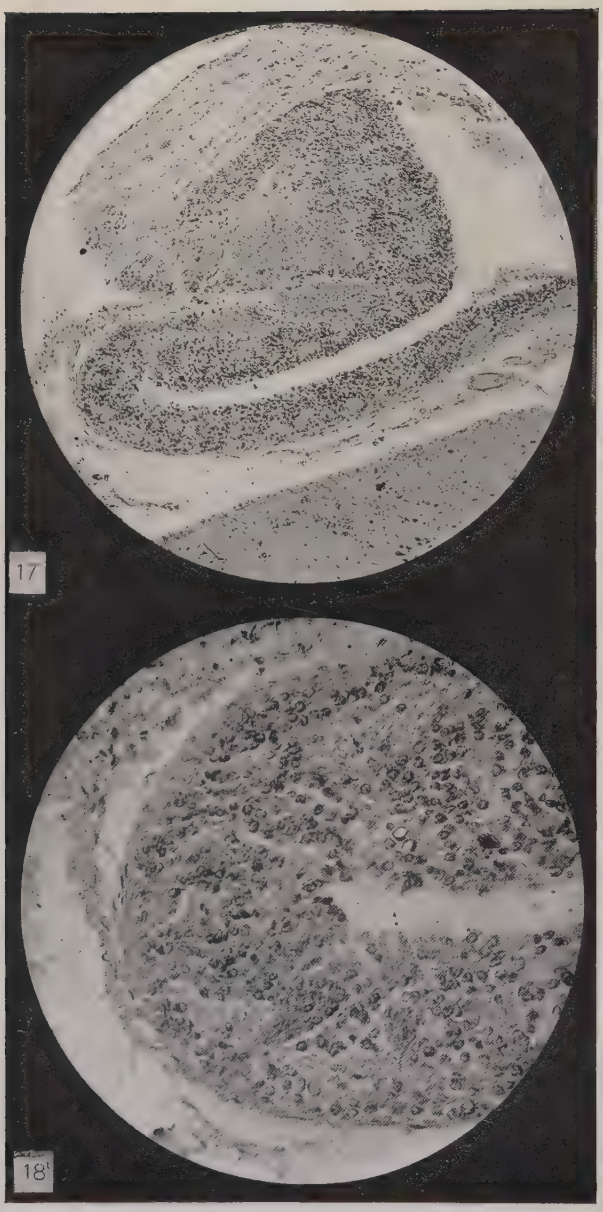


EXPLANATION OF FIGURES

14 Longitudinal section of epiphysis of type shown in figs. 3 and 4. Epiphyseal nerve-fibers connect the habenular (superior) with the posterior commissure. The cellular elements of the epiphysis are similar to, and continuous with, those of the habenular commissure. × 100.

15 Sketch of a follicular collection of cells and neuroglia fibers from superficial region of the epiphysis of fig. 14. The mass is separated laterally from other similar masses by bundles of nerve fibers. Both neuroglia and less highly differentiated ependymal cells are shown (technique; Müller-formal, iron-haematoxylin). × 600.

16 Typical neuroglia cells from epiphysis of fig. 14. The coarse neuroglia fibers illustrated here and in fig. 15 are found only among the cells of the epiphysis and here mostly superficially. × 600.



EXPLANATION OF FIGURES

17 Photomicrograph of short tubular type of epiphysis to show the follicular arrangement of the cells.

18 More highly magnified photomicrograph of portion of fig. 17.

pials, classified as the lowest mammals on numerous anatomic and physiologic grounds, also seem to have the most primitive type of mammalian pineal organ) shown in the circumstance that among rodents (*e.g.* guinea-pig, Studnicka, '05), usually classified as very low in the mammalian scale, this body is a long solid structure, a condition most probably due to greater proliferative activity among cells of an original tube. The adult form of epiphysis in higher mammals, for instance sheep and man, can readily be conceived as developed from the simple cup-form of opossum (marsupials?) by increase in proliferative activity among the parenchymal cells, and the inclusion of more or less numerous subdivisions of the original lumen in the shape of alveoli;[1] follicles being derivatives of the latter in consequence of still further cell proliferation.

Regarding the question of functional significance, observations on the opossum indicate that the pineal organ of mammals is unimportant in body metabolism. This is not necessarily an admission that it elaborates no secretion, which may even exert certain specific effects, but only that it is not essential either directly or indirectly for the normal conduct of the vegetative functions, as are the secretions of other of the better understood ductless glands. If animals like the opossum can subsist with a mere vestige of the pineal gland apparently not different from the habenular commissure, and possibly representing the proximal remnant of a more significant structure in reptiles, the definite effects of intravenous injections of extracts of the pineal body of the sheep (such as lowering of arterial blood pressure, and diuresis—Eyster and Jordan, '11) may have no real significance as indicating an important physiologic function for this organ. This theoretical conclusion accords well with the experimental

[1] A careful microscopic study of the pineal body of foetal sheep has convinced me that in this form the 'alveoli' do not arise, as suggested, from the original lumen, and as is stated to be the case for man; but they are in reality cysts. The latter are obliterated during the early months of postnatal life by the extensive proliferation of neighboring cells. Thus in many instances 'cysts' are the forerunners of 'follicles.' In still another point, then, the long tubular variation with 'alveoli' in the adult opossum represents an embryonic phase in higher mammals; *e.g.*, sheep.

findings of Exner and Boese ('10) on rabbits in which the pineal body was extirpated without effect upon growth or the appearance of sexual maturity; and with my own observation that among eleven pineal glands examined in cats, two were cystic and pedunculated, consisting of a mere shell of fibro-cellular protoplasm, without having had any apparent untoward effect.

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THE GELATIN METHOD OF PRESERVING ANATOMICAL SPECIMENS

WITH ESPECIAL REFERENCE TO NEUROLOGICAL PREPARATIONS

MERVIN T. SUDLER AND W. J. BAUMGARTNER

From the Anatomical Laboratory of the University of Kansas

TWO FIGURES

In the study of the anatomy of the central nervous system, methods and technique are relatively more important than in the study of other parts of the body. Muscles and bones are easy to demonstrate even to a beginner, but in the brain only the superficial and large parts stand out, even in the freshest material, and when the smaller superficial and internal structures which have taken anatomists centuries to observe are to be made plain it is evident that it can be done only with some difficulty, or by using some special technique to emphasize or preserve them.

The following method is the result of an effort to prepare material in accordance with these principles and to decrease the difficulties of the beginner in such a complex subject. These methods taken singly are not new, but combined they have given us better results than other methods we have used or seen.

The brains are removed as fresh as possible, hardened in 10 per cent formalin and thoroughly washed. They are then sectioned in the plane desired with a knife whose blade is about 18 inches long and quite thin. Such a knife is known to the hardware trade as a 'ham slicer.'

These sections are then stained several days in a solution of borax carmine that is diluted so that the solution is just well colored with the carmine and to which about 10 per cent of hydrochloric acid has been added. They are again thoroughly washed, by soaking in a relatively large quantity of dilute hydrochloric acid and water.

If labels are desired they are written on good paper with water proof ink and pinned fast by means of small 'ribbon' pins. Figures may be used and these correspond to a key mounted in the gelatin with the

specimen. The method of preparing the gelatin is that introduced by W. H. Watters of Boston:[1]

Solution no. 1

Potassium acetate	100 gms.
Glycerin	200 cc.
Water	1000 cc.

This solution is simply the permanent fluid for Kaiserling preparations.

Gelatine solution

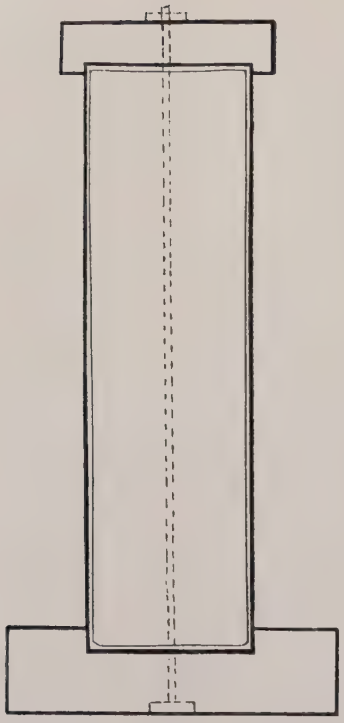
Gelatin	200 gms.
Solution no. 1	3000 cc.

As great care is required in the preparation of this last mixture, its technique will be described in full before commenting upon the mounting of the specimen. For some time we recommended soaking the gelatin in no. 1, for one or two days, but later have obtained better results by combining the two and immediately heating. About three or four liters are placed in a good agate-ware pail, which is placed directly over the gas stove, the entire solution being brought to the boiling point in the shortest possible time. Care must be taken to prevent burning, although the danger is not great. When a temperature of about 55° C. has been reached, and the gelatin is nearly all melted, the white of one egg is added for every liter present, and the entire solution is rendered strongly acid by acetic acid. The coagulated white of egg helps to clarify, as does also the acetic acid. In addition, the acid probably renders the medium a better color conserver. As soon as boiling becomes active, the hot preparation is poured into a filter with two thicknesses of paper, and the clear solution is collected in the stock jar. When ribbed funnels are used no difficulty is experienced in the process, but with the smooth ones more rapid results are attained by placing the whole apparatus into a large steam sterilizer, where the gelatin will not solidify. After solidification, a crystal of thymol placed on top of the stock solution will effectually prevent the appearance of fungi.

The sections are now placed in glass dishes of the proper size and shape. The ones best suited for brain sections are 15 cm. x 15 cm. x 25 mm., covered with the warm gelatin, and one drop of formalin added for every 20 cc. of the solution. A good margin should be left above the top of

[1] The gelatin method of preserving specimens, by W. H. Watters, The Medical Record, Dec. 22, 1906.

1



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the gelatin. The whole is then set away and allowed to harden. Then melted white vaseline is poured on, making a layer from one-half to one inch thick. This effectively prevents any evaporation. The glass top is then fastened on the jar with Canada balsam or cement. If there is too much formalin added, or if there is any left in the specimen, the gelatin becomes cloudy and shrinks. If there is too little, liquefaction and putrefaction and attendant inconvenience results. If there is a proper amount, the specimens remain unchanged, and we have some that are now three years old, and in exactly the same condition as when originally mounted.

For the sake of convenience wooden frames are made to hold three jars each. Figs. 1 and 2 show the construction of these.[2]

These methods have proven so successful that we have mounted a series of cross sections of the leg in the same way, also longitudinal sections of the head and brain dissections. At present we are preparing to mount dissections of the eye, kidneys, genital organs, and other structures that lend themselves to this method of preparation. The usefulness of these preparations are shown by the fact that students use them continually in preference to models, plates, or any artificial representations of the organs.

[2] The frames are made of oak and the grooves cut to fit the size of the particular jar. Blotting paper or felt is placed in these grooves to make the pressure even and the nuts on the brass bolts are put down carefully.

REPORT UPON THE COLLECTION OF HUMAN EMBRYOS AT THE JOHNS HOPKINS UNIVERSITY

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About twenty years ago I wrote a note for the American Naturalist asking for human embryological specimens. At that time my collection consisted of two embryos, one of which was in an excellent state of preservation. This I had carried as an offering to my teacher, Professor His, who would not accept it but returned it to me with several series from his own collection, including his well-known embryo No. XLIV (Bff). "These," he said, "will make a nucleus for your own collection. It will give me immense pleasure to see publications coming from new sources."

The misplaced note in The Naturalist brought no return nor was the reward from Minot's legacy to write numerous articles in the Reference Handbook on various phases of human embryology any better. But fate was with me for I concentrated my energies upon embryo No. 2 which not only taught me the method of reconstruction in wax but also served as a basis for my career in anatomy. I am proud of No. 2. At that time its effigy was the most elaborate reconstruction of an embryo in existence; it was the first reconstruction of an embryo made in America and I always think in human anatomy in relation to No. 2.

The numerous wax plates required in making the reconstruction of No. 2 and the form of the various organs as revealed in piling their pieces attracted the attention of various medical friends, who in the course of time supplied me with new embryos for study. They naturally brought their questions with the specimens. I was constantly asked: "How old is the embryo?" "What caused the abortion?" and "Could it have been prevented?" An attempt to answer these questions as well as other information served to satisfy the scientifically inclined, and soon I found a large number of physicians willing to

coöperate with me. This number was enlarged through the publication of several papers outlining my field of work and numerous letters for specimens in many medical journals. Thus it came about that collaborators were secured and many pleasant hours have been passed in conversation and discussion with them. This interest is by no means confined to physicians with whom I have personal acquaintance, but includes many whom I have never seen. The correspondence with these has often been extensive and long continued, their letters forming valuable notes which belong to the collection.

The making of a show collection will not satisfy the curiosity of thinking physicians very long, but they require rightly that their labors be rewarded by substantial contributions to embryological science. The anatomy of embryos will occupy much of our attention for some time to come. In case embryos studied are young the various structures of the whole specimen can be considered to advantage, but our powers are limited and only an individual system, organ, tissue or region can be followed in older embryos from stage to stage. The various embryos must be classified and standardized, the membranes must be studied anew, and abnormal specimens must be recognized and considered in relation to the cause which produced the deformity. So a single worker makes headway slowly and even a large number of experts with the aid of students and technicians cannot do justice to representative collections of specimens. Some aid has been secured by enlisting investigators in other institutions in studying this collection, and it is to be hoped that this may continue to a much greater extent in the future. As matters now are it will take a very long time before human anatomy rests entirely upon an embryological basis, and we should organize our forces in order to reduce the time as much as possible. His has proposed that an Embryological Institute be organized with this end in view, in which human embryologists coöperate in their work much as is done in the Brain Commission. The example in this direction set by the astronomers is still better and should be followed. My specimens would be placed at the disposal of a joint commission and would help to make a good beginning. As long as the methods of investigation in this subject remain as they are this collection will be of value; later it will still be of historical interest.

But I must come back from dreamland and state what can be done single-handed. At first we were fortunate if specimens came fairly well preserved in alcohol; too often they were injured or badly preserved. The introduction of formalin as a preservative gave us much better

specimens, and now perfectly fresh and sometimes living embryos are brought to us. These are preserved by the more refined methods and often the blood vessels are injected. The collection now includes a representative series of embryos and foetuses, from 15 mm. upward, with the blood vessels well injected.

Although the collection is well illustrated with numerous unpublished drawings and photographs, an effort is being made to record more elaborately unusually important stages and perfect specimens with many careful drawings and studies before they are cut into serial sections. The histories, although extensive, are becoming better and better. These bear upon the cause of the abortion; the nature of the injury in case it is mechanical, and the embryo has been unwittingly experimented upon; and the disease of the uterus in case the specimen is pathological. Reactions between leucocytes and syncytium are found to be pronounced and moles and monsters seem to bear relation to unskilled obstetricians as well as to the social evil. Studies in this direction must be made on a large scale to establish certain points of great value to medicine and to the race. A research institution or the coöperation of a group of obstetrical and gynecological clinics will be required to undertake the work before such questions can be answered. The routine work to be done is much too great for a single individual to undertake.

In the 533 specimens recorded under 500 numbers there are 50 normal embryos and 105 pathological under 8 mm. in length, that is, under six weeks old. Between 9 and 25 mm. there are 133 normal embryos and 66 pathological. In the whole collection there are 335 normal specimens and 198 pathological. Among the abortions of the first six weeks of pregnancy nearly 68 per cent of the specimens are pathological, from the sixth to the end of the eighth, 34 per cent, and during the remaining seven months but 18 per cent. From these figures as well as from my experience in the study of tubal pregnancy the conclusion may be drawn that a much larger percentage of fertilized ova are not implanted, escape observation and are lost. It would be interesting in this connection to compare collections of ova obtained from communities free from venereal disease with those in which syphilis and gonorrhoea are quite general. In the latter case abortions should be more common and the percentage of monsters should be greater.

Since it is established that monsters arise from normal eggs in an unhealthy environment the hope that we may be able to diminish their number is not visionary. Moles, or pathological ova, which are of far more common occurrence might be eliminated altogether.

It is necessary to determine with much greater precision than has been done the norm of both the embryo and its membranes for each stage of development. Much of the material for this study is at hand but before this is undertaken it will be necessary to establish the various stages. We have been in the habit of classifying embryos according to age, which is by no means a satisfactory method. An index dependent upon the length of the embryo is used by embryologists but for well-known reasons this also leads to confusion. It will be necessary to establish stages based upon the degree of development. For example, the embryos which are from 2 to 3 mm. long and are believed to be from two to four weeks old, might arbitrarily be called Stage H, leaving the first letters of the alphabet to represent earlier stages. At this time the myotomes are appearing and an embryo with two myotomes could be called Stage H_2, one with three myotomes Stage H_3, and so on. Later we could determine the degree of development of each organ and tissue and then refine the subdivision of stages still more. It may turn out that the organs are developed unequally in embryos of the same stage and this would be an observation of great importance.

When embryos have been standardized in this way we shall find that specimens of the same stage vary in length even when measured accurately in the fresh state. We may also find when the ages have been determined with greater precision, that the rapidity of development is not constant.

Since the unfertilized ovum has been observed in the uterine tube by Hyrtl and since an ovum 2 mm. in diameter has been found by Teacher there is every reason to hope that all stages of development will soon be found. Operations which expose the pelvic organs are now so common that if the gynecologist will only show the proper interest and look with especial care when a fresh corpus luteum is seen, the desired specimens will not remain hidden much longer.

There is an abundance of material at hand to study the growth of foetuses. The establishment of stages will necessitate the extension of the physical anthropological measurements downward through the foetus to the embryo. We should have tables which will tell us, for example, the length of each bone, the length of the brain, the degree of the development of its cortex, etc., for each stage. It is almost needless to add that coöperative studies of this kind will necessitate the introduction of a uniform terminology to articulate with the B N A.

In recent years a large number of foetuses as well as embryos have been injected in order to study the blood vessels with much greater

care. A number of the specimens came into our hands still alive, which made it possible to obtain complete vascular injection in embryos less than 20 mm long. In the catalogue they are marked [i]. It is now within our reach to give a satisfactory account of the development of the vascular tree of each organ, and in the course of time the exact extent of the lymphatic system in the human embryo will also be revealed by the injection method.

Many specimens have been clarified in caustic potash and glycerine to show the extent of ossification; these have been marked [k] in the catalogue. About 100 specimens less than 100 mm. long have been prepared in this way, and much more material is at hand for similar treatment. This work can be extended to show the extent of chondrification in embryos from which the organs have been removed for study. This brings me to the studies in organogeny which needs an abundance of whole organs to determine their form, as everything cannot be reconstructed. The tissues are well represented in serial sections of earlier stages and for older foetuses individual tissues from various stages of perfectly fresh specimens have been fixed and preserved by the best methods. A great field opens to us for the study of histogenesis which binds embryology to histology to make the foundation for scientific anatomy. Here the method of attack is also experimental and the horizon extends to include physiology, teratology and pathology.

Nearly 300 specimens were sent to me by physicians residing in Maryland. About 40 came from New York, 30 each from Ohio and the District of Columbia, and 25 from Massachusetts. Between 5 and 10 came from each of the following states: Iowa, Illinois, Wisconsin, California, New Jersey, Minnesota, Maine and Michigan, while smaller numbers were received from fifteen other states and countries.

One hundred publications are based, most of them entirely, upon this collection. The list of papers includes the chapters in the Manual of Human Embryology; this makes the data complete up to 1911. In a way this report may be considered a turning point in the history of the collection, as the Manual contains an inventory of the literature upon human embryology and is based upon this as well as upon other collections. The Manual may be viewed as a by-product, for it has been produced by investigators whose chief occupation has been teaching, and the volumes have been published generously by Hirzel of Leipzig and Lippincott of Philadelphia. It is not dependent upon a single research grant. If "to him that hath shall be given" applies to this effort we have every reason to hope for a far more elaborate display

in the second edition. The "Institute of Human Embryology" must do this work; it should enlist the energies of all competent investigators in this subject, the necessary material should be placed at their disposal, and research funds should be available to aid them in their work. I firmly believe that such a coöperative organization would produce more valuable results than is possible if our efforts remain divided. Gross human anatomy as a science is bankrupt. It is made solvent through embryology, which alone illuminates it.

LIST OF EMBRYOS

NOTE. The abbreviations in parentheses are as follows:

The first figure gives the length of the embryo from crown to rump in millimeters. The letter following indicates the direction of the section; T means transverse, S. Means sagittal, and C means coronal. The figure following this sign gives the thickness of the section in μ. The words *good*, *fair* or *poor* indicate the quality of the series. In case the specimen is pathological, abnormal or is treated in some special way this is marked in brackets; thus,

♂ = male; ♀ = female; a = abnormal; i = injected;
p = pathological; k = cleared in KOH; t = tubal pregnancy

Following the abbreviations for each specimen is the name and address of the physician from whom it was obtained. If no address is given Baltimore is understood. The figures after the name refer to papers with corresponding numbers in the bibliography based upon this specimen. In case a number is in italics it indicates that this specimen is illustrated in that paper.

1. (4.5, T, 10, poor.) Dr. Gavin, 13, 21, 27, 40, 41, 63, 75, 83, 91.
2. (7, T, 15, good.) Dr. C. O. Miller, *1*, *2*, 4, *5*, *6*, *7*, 8, 9, *10*, *11*, *12*, 13, *14*, *15*, *19*, 21, *24*, 27, *28*, *29*, *30*, *32* 34, 35, *36*, *39*, 40, 41, *45*, *46*, *47*, *48*, *49*, *50*, 52, 54, *56*, *58*, 62, 63, *68*, *71*, *73*, 75, *76*, 83, *85*, *86*, *87*, *90*, 91 *96*, 98.
3. (2.2, T, 10, poor.) Prof. His, Leipzig, Germany, *10*, 30, 40, 63, *74*, 91.
4. (7, T, 10, fair.) Dr. Williams, 10, 30, 40, 41, 63, 91.
5. (18.5, T, 20, fair.) Dr. Kittredge, Nashua, N. H., 10, 13, 21, 27, 30, 40, 41, 63, 75, 83, 91.
6. (24, T, 20, good, [♀].) Dr. C. O. Miller, 4, *10*, *11*, 13, *15*, *19*, 21, *22*, 27, *30*, 40, 57, 63, *68*, *75*, 82, 83, 91, *96*, 97.
7. (19.5, T, 40, poor.) Dr. Booker, 30, 40, 57, 63, 91.
8. (17, T, 40, poor.) Dr. Ritter, Brooklyn, N. Y., 10, 30, 40, 63, 83, 91.
9. (17.5, T, 20, fair, [♀].) Dr. Eyeleshymer, Chicago, *10*, *11*, *15*, *19*, *22*, *30*, 40, 41, 57, *60*, 63, *68*, 83, 91.
10. (24, T, 40, fair.) Dr. W. S. Miller, Madison, Wis., *10*, *11*, *15*, 21, *30*, 40, *56*, 57, *60*, 63, *68*, 75, 83, 91.
11. (.8, S, 10, fair [p].) Dr. Kittredge, Nashua, N. H., *3*, *4*, *10*, 12, *21*, 27, *30*, *33*, 40, 48, 62, *75*, 83.
12. (2.2, T, 10, good.) Dr. Ellis, Elkton, Md., 4, *10*, *11*, *12*, 13, *15*, *19*, *21*, *24*, 27, *28*, *30*, *32*, 36, *39*, 40, 41, 45, *47*, *48*, 55, 59, 63, *68*, *75*, 83, *84*, *85*, *87*, *90*, 91, *98*.
13. (1.4, S, 10, fair [p].) Prof. His, Leipzig, Germany, 10, *21*, 30, *33*, 37, 40, 63, *75*, 91.
14. (1.5, S, 10, fair [p].) Dr. Friedenwald, 10, *21*, 30, *33*, 40, 63, *75*.
15. (6.) Dr. Hoge, Richmond, Va., 63, 83.
16. (7.) Dr. Sherwood, 10, 13, 21, 27, 40, 63, 75, 83.
17. (18, S, 50 & 100, poor.) Dr. Cottell, Louisville, Ky., 10, 13, 21, 27, 30, 40, *56*, 57, *58*, 63, 75, 83, 91.
18. (7, T, 20, fair.) Dr. Douglass, Nashville, Tenn., *10*, 13, *19*, 21, 27, *30*, 40, 41, *48*, 63, 75, 83, 91.
19. (5.5, T, 20, poor.) Dr. Williams, *10*, 13, *19*, *21*, 27, *30*, *38*, 40, 41, 63, 75, 83, 91.
20. (50, fair, [p].) Dr. Williams, 10, *21*, 37, 40, 63, *75*.
21. (5.5, T, 20, fair, [p].) Dr. Cullen, London, Canada, 10, *21*, 30, *33*, *40*, 63, *75*, *84*.
22. (20, T, 50, good, [♂].) Dr. Snively, Waynesboro, Penn., *10*, *12*, 13, *21*, 25, 27, *28*, *30*, *32*. *36*, *39*, 40, 41, 42, *47*, 48, 52, 53, 54, *56*, 57, *58*, 62, 63, *68*, 69, *71*, *73*, 75, *78*, 81, 82, *83*, *85*, *86*, *90*, 91, *93*, 97, 98.
23. (70, T, 100, good, [♀].) Dr. Snively, Waynesboro, Penn., 13, 21, 27, 40, 42, *58*, 63, 83, 91.
24. (1, T, 20, good, [p].) Dr. C. O. Miller. 10, *21*, 30, *33*, 40, 63, *75*.
25. (6, S, 50, good, [p].) Dr. Lord. *21*, *33*, 37, 40, 63, *75*.
26. (30.) Dr. Simon, 13, 21, 27, 40, 63, 75, 83.
27. (23.) Dr. Thayer, 13, 21, 27, 40, 63, 75, 83.
28. (19.) Dr. Sewall, Denver, Col., 10, 13, 21, 27, 30, 40, *60*, 63, 75, 83.
29. (S, 50, good, [p].) Dr. Booker, 10, 21, 33, 37, 40, 63, 75.
30. (60.) Dr. Snively, Waynesboro, Penn., 13, 21, 27, 40, 63, 75, 83.
31. (24,) Dr. Ballard, 13, 21, 27, 40, 63, 75, 83.
32. (9, S, 50, good, [p].) Dr. Booker, 10, *21*, *33*, 37, 40, 63, *75*, *84*.
33. (27.) Dr. Robb, Cleveland, Ohio, 63, 83.
34. (80, T, 50, good, [♂].) Dr. Ellis, Elkton, Md., *10*, *11*, 13, *15*, 18, 21, *22*, 27, *30*, 40, 42, 63, 83, 91.
35. (13.) Dr. C. O. Miller, 13, 21, 40, 63, 75, 83.
36. Dr. Gould, Philadelphia, 63.
37. (2, T, 50, poor, [p].) Dr. Gould, Philadelphia, 10, *21*, *33*, 40, 63, *75*.

38. (53.) 83.
39. (40.) 83.
40. (22.) 83.
41. (48.) Dr, Williams, 63, 83.
42. (18, [k].) Dr. Wills, Los Angeles, Cal., 10, 13, 21, 27, 30, 40, 63, 69, 75, 83.
43. (16, S, 50, good, [♂].) Dr. Booker, *10*, *12*, *14*, *19*, *24*, *25*, 26, *28*, *30*, *32*, *36*, 40, 41, 52, 54, 57, 61, 63, 65, 83, *87*, 91, *93*, *96*, *98*.
44. (70; T, 100, good, [♂].) Dr. Snively, Waynesboro, Penn. 42, *58*, 63, 83, 91.
45. (28, T, 50, good, [♂].) Dr. Douglas, *10*, *11*, 13, *15*, 18, 21, *22*, 27, *30*, *31*, 40, 41, 42, 54, *56*, 57, *58*, 63, 75, 81, 83, 91.
46. (135.) Dr. Taylor, 13, 21, 27, 40, 63, 83.
47. (65.) 83.
48. (130, T, 100, good, [♀].) Dr. Wilson, Worcester, Mass., 10, *11*, *15*, *22*, 30, 40, 41, 42, 54, 63, 83, 91.
49. (70.) 13, 21, 27, 40, 63, 83.
50. (120.) Dr. Cullen, 63, 83.
51. (65.) Dr. Gavin, 63, 83.
52. (33.) Dr. Gavin, 13, 21, 27, 40, *60*, *62*, 83.
53. (15, [k].) Dr. McMorris, Belle Plaine, Ia., 10, 40, 63, 69, 75, 83.
54. (11, T, 50, & 100 fair, [p].) Dr. McMorris, Belle Plaine, Ia., 21, 33, 37, 40, 63, 75, 83.
55. (S, 50, good, [p].) Dr. Watson, 10, 21, 33, 37, 40, 63, 75.
56. (24, [k],) Dr. Flexner, 63, 83.
57. (23, S, 50, poor, [♂].) Dr. Howard, Cleveland, Ohio, 10, 13, 21, 27, 30, 40, 41, *56*, 57, 63, 75, 83, 91, 96.
58. (6, T, 50 & 100, good, [p].) Dr. Howard, Cleveland, Ohio, *21*, 30, 33, 40, 63, *75*.
59. (10, [k].) Dr. Neale, 63, 69, 83.
60. (8, S, 100, fair, [p].) Dr. Dobbin, 21, 33, 40, 63, 75.
61. (T, 20, fair, [p].) Dr. Williams, 63, 83.
62 (130.) Dr. Gibbs, 63, 83.
63. (5 weeks.) Dr. Zimmerman, 63.
64. (75,) Dr. Zimmerman, 16, 40, 63, 83.
65. (120.) Dr. Zimmerman, 16, 40, 63, 83.
66. (130.) Dr. Zimmerman, 63, 83.
67. (150.) Dr. Zimmerman, 63, 83.
68. (160.) Dr. Zimmerman, 63, 83.
69. (13, S, 50 & 100, good, [p].) Dr. Chabot, *21*, 33, 37, 40, 63, *75*.
70. (good, [p].) Dr. Ellis, Elkton, Md. *21*, 33, 37, 40, 63, *75*.
71. (T, 20, good, [p].) Dr. Whitcomb, Greenwich, N. Y. 21, 37, 40, 63, *75*, 83.
72. (23.) Dr. Arthur, 13, 21, 27, 33, 40, 63, 75, 83.
73. (30.) Dr. Irving Miller, 63.
74. (16, T, 50, good, [♂].) Dr. Irving Miller, *12*, *24*, 40, 41, *50*, 54, *56*, 57, 63, 82, 83, *87*, 91, 97.
75. (30, S, 50, good, [♂].) Dr. A. C. Ferguson, Berwick, Me., *31*, 34, 40, 41, 54, *56*, 57, 63, *71*, 83, 91.
76. (4.5, T, 20, good.) Dr. Mitchell, Chicago, *12*, 13, 14, 21, *24*, 27, *28*, *32*, *34*, 40, 41, 48, 52, 56, *58*, 63, *68*, *75*, *85*, *87*, 91, 98.
77. (S, 20, good, [p].) Dr. Horn, *21*, 33, 37, 40, 63, *75*, 83, *84*.
78. (1, S, 50, fair, [p].) Dr. Stoner, Harlan, Ia., *21*, *33*, 40, 63, *75*, *84*.
79. (33, S, 100, good, [p].) Dr. Briggs, Blackville, S. C., 13, *18*, *21*, 27, 33, 40, *56*, 57, *58*, 63, *75*, 83, *84*, *85*.
80. (5, T, 20, good). Dr. Branham, 13, *21*, *24*, 27, *28*, *32*, *34*, 40, 41, 48, 52, 54, *58*, 59, 63, *68*, *75*, 83, *84*, *85*, *87*, 91, *96*, *98*.
81. (15, S, 50, & 100, fair, [p].) Dr. Branham, 13, *21*, 27, 33, 40, 63, *75*, 81.
82. (good, [p].) Dr. Cassidy, *21*, 33, 37, *38*, 40, *62*, *75*, 82.
83. (18.) Dr. McGraw, Pittsburg, Pa., 63.
84. (50, T, 50, good, [♀].) Dr. Duval, 41, 54, *56*, *58*, 63, *82*, 83, *85*, 91.
85. (80.) Dr. Jump, Diamond, Cal., *56*, 63, 83.
86. (30, C, 50, good, [♂].) Dr. Billingslea, *31*, 40, 41, *56*, *57*, 62, 63, *71*, 83, *90*, 91, *97*.
87. (4, T, 20, fair.) Dr. Cole, Peru, Ill., 13, *21*, 27, 30, *33*, 40, 63, *75*, 83, 91, 98.
88. (8, T, 50, & 100, poor.) Dr. Brumme, Detroit, 13, *21*, 27, 40, 41, 53, 54, 63, 75, 83, 91.
89. (25.) Dr. Brumme, Detroit, *60*, 63, 83.
90a. (30.) Dr. Brumme, Detroit, *25*, 40, 63, 83.
90b. (18.) Dr. Brumme, Detroit, 63, 83.
90c. (17,) Dr. Brumme, Detroit, 63, 83.
90d. (18.) Dr. Brumme, Detroit, 63, 83.
91. (20.) Dr. Haynes, Brooklyn, N. Y., 63.
92. (70.) Dr. Ballard, 13, 27, 40, 63, 83.
93. (C, 50 & 100 [p].) Dr. Cassidy, 21, 33, 37, 40, 63, 75, 83.
94. (20, S, 50, fair, [p].) Dr. Knill, Detroit, 13, *21*, 27, 33, 40, 57, 63, *75*, 83.
95. (46, S, 100, good, [♀].) Dr. Watson, 13, 21, *31*, 40, 41, 57, 63, 75, 82, 91.
96. (50, S, 100, good, [♀].) Dr. Spencer, San Francisco, 13, 21, 27, 31, 40, 41, 57, *58*, 63, 75, 82, 83, 91, *97*.
97. (7, S, 50, good, [p].) Dr. Goldman, *21*, 33, 40, *56*, 63, *75*, 83.
98. (160.) Dr. Atkinson, 13, 16, 21, 40, 63, 83.
99. (27.) Dr. Carr, Durham, N. C., 13, 21, 27, 40, 63, 75, 83.
100. (27, S, 50, poor.) Dr. Pole, 41, 57, 63, 83, 91.
101. Dr. Pole, 63.
102. Dr. Pole, 63.
103. Dr. Pole, 63.
104. (12, S, 50, fair, [p].) Dr. West, Bellaire, Ohio, *21*, 33, 40, 63, *75*.
105. (48.) Dr. Watson, 13, 21, 27, 40, 41, 63, 83.
106. (17, T, 50, good.) Dr. Gardner, 13, *21*, 27, *28*, 36, 40, 41, 57, *58*, 63, 75, 82, 83, 91, 97.
107. (fair, [p].) Dr. Gibbs, 63.
108. (22, S, 45, fair, [♂].) Dr. Sudler, 57, *58*, 63, 83, *85*, 91, 96
109. (10.5, T, 20, good, [t].) Dr, Cushing, 13, 21, *24*, *25*, 27, *28*, *32*, 34, *36*, *39*, 40, 41, *45*, *46*, *47*, *50*, *56*, *58*, 62, 63, *68*, *71*, *73*, 75, *76*, *82*, 83, *85*, *86*, *87*, *90*, 91, *93*, *96*, *97*, 98, *99*.

110. (8, S, 100, fair, [p].) Dr. West, Bellaire, Ohio, *21*, 33, 37, 40, 63, *75*.
111. (1.5, T, 10, poor, [p].) Dr. Gray, Washington, 63.
112. (4, S, 10, poor.) Dr. Gray, Washington, 63, 91.
113. (8, S, 10, fair.) Dr. Gray, Washington, *24*, 40, 41, 48, 54, 63, 83, *87*, 91, 98.
114. (10, S, 10, fair.) Dr. Gray, Washington, *24*, 40, 41, 52, 54, 61, 63, 83, 91, 98.
115. (3, T, 20, good, [p].) Dr. Atkinson, *21*, 33, 37, 40, 63, *75*, *84*.
116. (5, S, 20, good.) Dr. Ryan, Springfield, Ill., 13, 21, *24*, 27, 40, 41, 63, 75, 83, *87*, 91, 98.
117. (100,) Dr. Ballard, 13, 21, 27, 40, 63, *68*, 83.
118. (25.) Dr. Booker, 13, 21, 27, 40, 41, 63, 75, 83.
119. (C, 50, good, [p].) Dr. Biedler, 63.
120. (24.) Dr. Chittenden, Binghamton, N. Y., 63, 83, 91.
121. (210.) Dr. Ballard, 13, 21, 27, 40, 63, 83.
122. (5, S, 100, good, [p].) Dr. Williams, *21*, 33, 40, 63, *75*, *84*.
123. (2, S, 20, fair, [p].) Dr. Boldt, New York, *21*, 30, *33*, 37, 40, 63, *75*.
124. (35, S, 50 & 100, poor [p].) Dr. Cassidy, *21*, 33, 37, 40, 63, *75*, *84*.
125. (83.) Dr. Ballard, 63, 83.
126. (125.) Dr. Ballard, 63, 83.
127. (24.) Dr. Gundry, *21*, 40, 63, 75, 83.
128. (20, C, 50, good, [♂].) Dr. Lupton, *21*, 33, 34, 40, 63, *75*, 82, 83, *84*, 91, *93*, 97, 98.
129. (32.) Dr. Gundry, 21, *25*, 40, 63, *75*, 83.
130. (4, T, 20 & 100, poor, [p].) Dr. Saussure, Charleston, S. C., *21*, 30, *33*, 37, 40, 63, *75*, 83.
131. (90.) Dr. Watson, 63, *83*.
132. (15, T, 50, good, [p].) Dr. Lamb, Washington, *21*, 33, 37, 40, 63, *75*.
133. (12, C, 100, fair, [p].) Dr. Hundley, *21*, 33, 40, 63, *75*, *84*.
134. (9, good,]p[.) Dr. Sommer, Trenton, N. J., *21*, 30, *33*, 37, 40, 63, *75*, 91.
135. (9, T, 50, good, [p]). Dr. Mosely, *21*, 33, 37, 40, 63, *75*, *84*.
136. (4, C, 50, good, [p].) Dr. Campbell, Halifax, *21*, *24*, 33, 37, 40, 63, *75*, 83, *87*, 91.
137. (16, S, 50, fair, [p].) Dr. Watson, Baltimore, *21*, 30, 33, 40, 63, *75*.
138. (112.) Dr. Watson, 21, 27, 40, 41, 63, 83.
139. (55.) Dr. Boldt, New York, 41, 63, 83.
140. (40.) Dr. Johnson, Washington, 63, *75*, 83.
141. (8, S, 50, fair, [p].) Dr. West, Bellaire, Ohio, *21*, 33, 37, 40, 63, *75*.
142. (15, S, 50, good, [p].) Dr. Sommers, Trenton, N. J., *21*, 33, 37, 40, 63, *75*.
143. (25, S, 50, poor, [p].) Dr. Stick, Glenville, Pa., *21*, 30, 33, 37, 40, 63, *75*.
144. (14, S, 40, good, [♀].) Dr. Watson, 21, *24*, 26, 27, 28, 34, *36*, 40, 41, *49*, *50*, 52, 54, *56*, 57, *58*, 62, 63, 65, *71*, *73*, *75*, *78*, 82, *83*, *85*, *86*, *87*, *90*, 91, *92*, *93*, *96*, 97, 99.
145. (33, S, 50, & 100 good,]♂[.) Dr. Watson, 21, 27, 40, 48, 50, *56*, 57, *58*, 63, *73*, *75*, 83, *85*, 91, 96.
146. (95, T, 100, fair.) Dr. Watson, 21, 27, 40, 41, 63, 83, *90*, 91.
147. (1, S, 50, fair, [p].) Dr. Pole, *21*, 30, 33, 37, 40, 63, *75*.
148. (4.3, T, 10, good.) Dr. Hoen, *21*, *24*, 27, *28*, 40, 41, 43, 44, *49*, 55, *59*, 62, 63, *68*, *71*, 75, 77, *80*, 83, *87*, *90*, 91, 96, 98.
149. (130.) Dr. Hoen, 27, 33, 40, 41, 63, 83.
150. (5, S, 20, fair, [p].) Dr. Oertel, Augusta, Ga., 21, 33, 40, 63, 75.
151. (52.) Dr. Ramsey. 41, 63, 83.
152. (31, S, 100, poor, [p].) Dr. Boldt, New York, 21, 33, 40, 63, 75, 83.
153. (good, [p].) Dr. Stick, Glenville, Pa., 21, 33, 37, 40, 63, 75, 83.
154. ([t], [p].) Dr. Boldt, New York, 63, 75.
155. (30.) Dr. Kerr, Ithaca, N. Y., 63, 75, 83.
156. (12, [k].) Dr. Kerr, Ithaca, N. Y., 63, 69, 75, 83.
157. Dr. Russell, 63.
158. (2, S, 50, poor, [t], [p].) Dr. Howard, Cleveland, Ohio, 37, 40, 63, 75.
159. ([p].) Dr. Golden, Elkins, W. Va., 21, 37, 40, 63, 75.
160. (18.) Dr. MacCallum, 63, 75, 83.
161. (10, C, 50, fair, [p].) Dr. Cassidy, 21, 33, 40, 63, 75.
162. (1, T, 50, fair, [p].) Dr. Wanstall, *37*, 40, 63, *75*, *84*.
163. (9, T, 20, good.) Dr. Lamb, Washington, *24*, *25*, *28*, *32*, 34, *36*, *39*, 40, 41, *45*, *46*, *47*, 48, *50*, 52, 54, *56*, *58*, 62, 63, *68*, *71*, *73*, *75*, *83*, *85*, *86*, *87*, *90*, 91, 96, 97.
164. (3.5, T, 20, fair.) Dr. MacCallum, *24*, *32*, *34*, *38*, 40, 41, 52, 59, 63, 75, 83, *87*, 91, *98*.
165. ([t].) Dr. Sampson, Cambridge, Md., 63.
166. (2.5, T, 50, good, [p).) Dr. Cassett, *37*, 40, 63, 75.
167. (14.5, [k].) Dr. Ritter, Brooklyn, N. Y., *28*, 40, 48, 62, 69, 75, 83.
168. (75, [k].) Dr. Lamb, Washington, 63, 69, 75, 83.
169. (52.) Dr. Watson, 41, 63, 83.
170. (125, T, 100, poor.) Dr. Watson, 41, 63, 83, 91.
171. (60.) Dr. Irving Miller, 48, 63, 83.
172. (80, T, 100, good, [♀].) Dr. Watson, 54, 63, *82*, 83, 91, 97.
173. ([p].) Dr. Jump, Tesla Mines, Cal., 63, 75, 83.
174. (13, T, 50 & 100, good, [p].) Dr. Gibbs, 37, 40, 63, *75*.
175. (13, T, 20, good, [t].) Dr. Boldt, New York, *28*, *36*, 40, 41, *46*, *48*, 51, *52*, *56*, 57, *58*, 63, *71*, 75, 83, *85*, 91, 98, 99.
176. (38.) Dr. Kerr, Ithaca, N. Y., 48, 63, 75, 83.
177. (12. T, 50 & 100, good, [p].) Dr. Harrison, 37, 40, 63, *75*.
178. (35.) Dr. Cassidy, 57, 63, 75, 83.
179. (70, T, 50, poor, [t].) Dr. Stone, 41, 63, 91.
180. (2, T, 30, good, [p].) Dr. Dodge, Rochester, N. Y., 37, 40, 63, 75.
181. ([p].) Dr. Lamb, Washington, 37, 40, 63, 75.
182. (50 & 100, fair, [p].) Dr. Lamb, Washington, 37, 40, 63, *75*.
183. (28, [t] [chorion cut].) Dr. Boldt, New York, 63, 83.
184. (50, S, 50 & 100, good [♀]. Dr. Russell, 48, 57, *58*, 63, 83, *85*, 91.
185. (good, [p].) Dr. Sabin, 37, 40, 63, 75.

186. (3.5, T, 20, good.) Dr. Boldt, New York, *58*, 63, *68*, 75, 83, *85*, 91, 98.
187. (7, S, 20, fair, [p].) Dr. Cassidy, 48, 63, 75, 83, 91.
188. (17, T, 100, fair [p].) Dr. Sommer, Trenton, N. J., 37, 40, *56*, 57, 63, 75, 83.
189. (4, T, 50, good, [p].) Dr. Oertel, Augusta, Ga., 37, 40, 63, *75*.
190. ([p].) Dr. Ellis, Elkton, Md., 37, 40, 63, 75.
191. ([p].) Dr. Ellis, Elkton, Md., 37, 40, 63.
192. (27.) Dr. Larsen, Chicago, 63, 75, 83.
193. (40.) Dr. Fuchs, Loyal, Wis., 63, 83.
194. (21.) Dr. Lamb, Washington, 63, 75, 83.
195. ([p].) Dr. Lamb, Washington, 37, 40, 63, 75.
196. (3, C, 50, fair [p] [t].) Brödel Collection, 37, 41, 63, *75*.
197. (6 weeks, normal [t].) Dr. Little, 63.
198. (7, C, 100, fair, [p].) Dr. Larsen, Chicago, 37, 40, 63, *75*.
199. (35, S, 50, fair, [♀].) Dr.——, 57, 63, *75*, 83, 91.
200. (14, C, 50, fair, [p].) Dr. Skilling, Lonaconing, Md., Brödel Collection, 37, 40, 63, *75*, 83.
201. (20 T 50 good [p]). Dr. Shelly (Brödel Collection), 37, 40, 63, *75*, *84*.
202. (22, [k].) Dr. Ottley, *60*, 63, 69, 75, 83.
203. (28.) Dr. Fuchs, Loyal, Wis., 63, 75, 83.
204. ([p.]) Dr. Lamb, Washington, 37, 40, 63, 75.
205. (6, C, 50, good, [p].) Dr. Lamb, Washington, 37, 40, 63, 75.
206. (40.) Dr. Lamb, Washington, 41, 63, 75, 83.
207. (16, S, 100, fair, [p].) Dr. Horn, (Brödel Collection) 37, 40, 57, 63, *75*.
208. (7, S, 20, poor.) Dr. Dale, Lamont, Pa., 63, 75, 83, 91.
209. (3, T, 50, fair.) Dr. Sommer, Trenton, N. J., 55, 59, 63, 75, 91, 98.
210. (35.) Dr. Lamb, Washington, 63, 83.
211. (33, S, 50 & 100, good, [♀].) Dr. Spencer, San Francisco, 54, 57, 63, 75, 83, 91.
212. (15, T, 100, fair, [p].) Dr. West, Bellaire, Ohio, 63, 75.
213. (37.) Dr. Cassidy, 63, 75, 83.
214. (14, [k].) Dr. Hurdon, 63, 69, 75, 83.
215. (15, [p].) Dr. Unger, Mercersberg, Pa.,]Brödel Collection), 63, *75*.
216. (17, T, 50 & 100, poor.) Dr. Wegefarth (Brödel Collection), *56*, 57, *58*, 63, 75, 83, 91.
217. (45.) Dr. Merril, Stillwater, Minn., 63, 75, 83.
218. (42.) Brödel Collection, 41, 63, 83.
219. (115, S, 100, poor.) Brödel Collection, 41, 63, 83, 91.
220. (150, T, 100, poor,) Brödel Collection, 63, *90*, 91.
221. (7.5, S, 20, fair.) Dr. Perkins, Cleveland, Ohio, 52, *58*, 63, *75*, 83, 91, *98*.
222. ([p].) Dr. Steele, Cambridge, Md. (Brödel Collection), 63.
223. Dr. Wilkins (Brödel Collection), 63, *75*.
224. (40, S, 50 & 100, good, [♂].) Dr. West, Bellaire, Ohio, 54, 57, 63, 75, 82, 83, 91, 97.
225. (46, [i].) Dr. Wegefarth (Brödel Collection), 50, 63,
226. (24, T, 50 & 100, good, [p,♂],) Dr. West, Bellaire, Ohio, *56*, 57, 63, *75*.
227. (30, S, 50 & 100, good, [♀].) Dr. Ingle, 63, 75, 83, 91.
228. (3.5, S, 50, fair, [p].) Dr. West, Bellaire, Ohio, 63, *75*.
229. (19, S, 50, good, [♀].) Dr. Sandrock, *56*, 57, 63, *71*, 75, 83, 91, 96.
230. (60, S, 50, & 100, good, [p].) Dr. West, Bellaire, Ohio, 63, *75*.
231. (12, T, 100, poor.) Brödel Collection, 63, 83, 91.
232. (14, T, 100, fair, [p].) Brödel Collection, 63, *75*.
233. ([p].) Dr. Preston Miller, Hagerstown, Md. (Brödel Collection), 63, *75*.
234. (80, T, 50, good, [i].) Dr. Ashby (Brödel Collection), *50*, 63, *90*, 91.

234b. (65.) Brödel Collection, 50, 63.

235. (59, [i].) Dr. Linthicum, Savage, Md. (Brödel Collection), 50, 63.
236. (92, [i].) Dr. Wilson, Tilgham, Md. (Brödel Collection), 63.
237. (48, [i].) Dr. Todd, Mt. Washington, Md. (Brödel Collection), *50*, 63.
238. (90, [i].) Dr. Smart (Brödel Collection), 50, 63.
239. (3, T, 10, fair.) Dr. Morse, Boston, 63, 75, 83, *87*, 91.
240. (20, C, 20, good.) Dr. West, Bellaire, Ohio, 63, 69, 75, 83, 91, 98.
241. (6, T, 10, good.) Dr. Sandrock, *58*, 63, 75, 83, *85*, 91, *95*, 98.
242. (23, T, 40, fair [a].) Brödel Collection, 63, 75, 83, 91.
243. ([p].) Dr. Miller, Hagerstown, Md. (Brödel Collection), 63, *75*, *84*.
244. (4, T, 20, good, [p].) Dr. Kelly (Brödel Collection), 63, *75*.
245. (6, T, 5, poor.) Dr. Irving Miller, 63, 75, 83, 91.
246. (3, T, 20, fair, [p].) Dr. Wegefarth (Brödel Collection), 63, *75*.
247. (2.5, T, 20, fair, [p].) Dr. Seymour, Trappe, Md. (Brödel Collection), 63, 75.
248. (4.5, T, 40, poor.) Dr. Winternitz, 63, 75, 83, 91.
249. (37, T, 50, fair, [a].) Dr. Hektoen, Chicago, 63, 83, 91.
250. (2, S, 20, good, [p].) Dr. Sampson, 63, *75*, *84*, 91.
251. (9, S, 25 & 50, good, [p].) Dr. Ritter, Brooklyn, N. Y., 63, *75*.
252. (3, T, 20, good, [p].) Dr. Lamb, Washington, 63, *75*.
253. (3, T, 20, good, [p].) Brödel Collection, 63, *75*, 91.
254. ([i].), Brödel Collection.
255. (T, 50, [p].) Brödel Collection, 75.
256. (16, T, 25, & 50 fair, [t].) Dr. Austin, Boston, Mass., *75*, 83, *84*, 91, 98.
257. (T, 25 & 50, [p].) Dr. Lankford, *75*, *84*.
258. (13.) Dr. Pollock, 75.
259. (45.) Dr. Sandrock, 75, 83.
260. (52.) Dr. Burns, Memphis, Tenn., 83.
261. (90, [p].) Dr. Lewis, *75*.
262. (14, S, 25, poor, [p].) Dr. Glering, *75*.

263a. (20, [k].) Dr. Lyman, 83.

263b. (16, [k].) Dr. Lyman, 69, 83.

263b[1]. (34, [k].) Dr. Lyman, 69, 83.
263b[2]. (32, [k].) Dr. Lyman, 69, 83.
263c. (19, [k].) Dr. Lyman, 69, 83.
263d. (17, S, 50, good, [p].) Dr. Lyman, *75*.
264. (2.5, T, 50, good, [p].) Dr. Gardner, *75*.
265. ([Amnion].) Dr. Williams.
266. (33, [k].) Dr. Ashby, 69, 83.
267. (59.) Dr. Blades, 83, 91.
268. (22, S, 25 & 50, poor.) Dr. Kammerer, New York, *75*, 91.
269. (35.) Dr. Lewis, 75, 83.
270. (14, S, 25 & 50, good, [p].) Dr. Wilson, *75*.
271. (18, [k].) Dr. Dreifus, 69.
272. (34, [k].) Dr. Conradi, 69, 83.
273. (75.) Dr. Conradi, 83.
274. (31, [k].) Dr. Blades, 69, 75, 83.
275. (8, T, 25 & 50, good, [p].) Dr. Tobie, Portland, Me., *75*.
276. (13.5, S, 25 & 50, good, [p].) Dr. Stanley, Portland, Me., *75*.
277. (40.) Dr. Knipp.
278. (T, 20, good, [p].) Dr. Stanton, Albany, N. Y., *75*, 83, *84*, 91.
279. (T, 25 & 50, [p].) Dr. Kemp, *75*.
280. (T, 25, [p].) Dr. Magness, 75.
281. (185, S & T, 50' good, [medulla], [i].) Dr. Mayer.
282. (42, [k].) Dr. McGlannan, 69, 75, 83.
283a. ([21.) Dr. Conradi, 83.
283b. (19.) Dr. Conradi, 83.
283c. (25.) Dr. Conradi, 83.
284. (54, [k].) Dr. McCormick, *69*, 83.
285. (9, S, 25 & 50, good, [p].) Dr. Keown, *75*, *84*.
286. (60, [p].) Dr. Girdwood, *75*, *84*.
287. Dr. Parker.
288a. (77, C, 50, poor, [p].) Dr. Brülle, *75*,
288b. (57, [k].) Dr. Brülle, 69, 83.
288c. (11.) Dr. Brülle, 83.
289. (8, C, 20, poor, [p].) Dr. Brülle, 75, 91.
290. ([p].) Dr. Warren, Portland, Me., *75*.
291. (5, S, 25, [p].) Dr. Wegefarth (Brödel Collection), *75*.
292a. (3.5, T, 35 & 50, [p].) Dr. West, Bellaire, Ohio, *75*, *84*.
292b. Dr. West, Bellaire, Ohio.
293. (19, S, 50, [p].) Dr. Lamb, Washington, *75*, *84*, 91.
294. (35, [t], [i].) Brödel Collection.
295. (110, [p].) Dr. Miller, Hagerstown (Brödel Collection), *75*.
297. (17, C, 20, good.) Dr. Haynes, Boston, *82*, 83, 91, *97*, 98, 99.
297. (6, S, 25, [p].) Dr. Lamb, Washington, *75*, *84*.
298. ([t], [p].) Dr. Pearce, Albany, N. Y., *75*.
299. ([p]).) Dr. Barns, Memphis, Tenn., 75.
300. (73, [k].) Dr. Forsythe, *69*, 83.
301. (44.) Dr. Call, 75, 83.
302. (4, S, 25, [p].) Brödel Collection, *75*.
303. ([p].) Brödel Collection.
304. ([p].) Dr. Hunner (Brödel Collection), *75*, *84*.
305. (40.) Dr. Lamb, Washington, 83.
306a. (100, [a].) Dr. Conradi, 69, 83, 91.
306b. (105, [k].) Dr. Conradi, 69, 83.
306c. (75, [k].) Dr. Conradi, 69, 83.
306d. (82, [k].) Dr. Conradi, 83.
306f. (70, [k].) Dr. Conradi, 83.
306g. (110, [k].) Dr. Conradi, 83.
306h. (120, [k].) Mr. Conradi, 83.
307. (20, [t], [p].) Dr. Coe, New York, 75.
308. (84, [p].) Dr. Ballard, *75*, 83.
309. (4, S, 25, good, [p].) Dr. Steensland, Syracuse, N. Y., *75*.
310. ([p].) Dr. Watson, *75*, *84*.
311. (12.5, S, 25 & 50, good, [p].) Dr. Watson, *75*.
312. (8, S, 25, poor, [p].) Dr. Stanton, Albany, N. Y., *75*.
313. (36.) Dr. Knipp, 83.
314. (24, S, 50, fair, [t].) Dr. Pearce, Albany, N. Y., 83, 91.
315. (47.) Dr. Blades, 83.
316. (44, [p].) Dr. Simms, *75*.
317. (16, C, 20, good.) Dr. Pearce, Albany, N. Y., 75, *82*, 83, 91, *93*, 97, 98.
318. (2.5, T, 25, good.) Dr. Sommer, Trenton, N. J., 75, 83, 91.
319. (54.) Dr. Gibbs, 83.
320. (18, S, 25 & 50, [p].) Dr. Gibbs, *75*.
321. (2, T, 25, [p].) Dr. Wentz, Hanover, Penn., *75*.
322. (90.) Dr. West, Bellaire, Ohio, 83.
323. ([p].) Dr. Van Williams, *75*. *84*.
324. (3.5, T, [t], [p].) Brödel Collection, *75*.
325. (13, S, 15, [p].) Dr. Ballard, *75*.
326. (55, [k].) Dr. Rehberger, 69, 83.
327. (19.) Dr. Lamb, Washington, 83.
328. (4.5, S, 25 & 50, [p].) Dr. Pohlman, Bloomington, Ind., *75*, *84*.

329. (39. [k].) Dr. Myer, 69, 75, 83.
330a. (12, S, 25 & 50, [p].) Dr. West, Bellaire, Ohio, *75*.
330b. (12, S, 5 & 50, [p]) Dr. West, Bellaire, Ohio, *75*.
331. (220,) Dr. Boone, Bellaire, Ohio, 83.
332. (200.) Dr. Heath, Bellaire, Ohio.
333. (3rd month, [k].) Dr. Bloodgood, *69*.
334. (5, S, 25, [p].) Dr. Merrill, Stillwater, Minn., 75.
335. (190, [a].) Dr. Crotser, Petoskey, Mich.
336. (8, S, 50 good, [p].) Dr. West, Bellaire, Ohio, *75*.
337. (90.) Dr. Merrill, Stillwater, Minn., 83.
338a. (18, S, 25 & 50, [p].) Minot Collection, *75*, 91.
338b. (12.) Minot Collection.
338c. (5 weeks, [t].) Minot Collection.
338d. (11.5.) Minot Collection.
339. (16, S, 25 & 50, [p].) Minot Collection, *75*.
340. (6. S, 15 & 50, [p].) Minot Collection, *75*, *84*.
341. (14, S, 25 & 50, [p].) Minot Collection, *75*.
342. (S, 25 & 50 [t]. [p].) Minot Collection, *75*.
343. (11, S, 25 & 50, good, [p].) Minot Collection, *75*, *84*.
344. (16, S, 50, [p].) Minot Collection, *75*.
345. (19, S, 25 & 50, [p].) Minot Collection, *75*.
346. (13, S, 25 & 50, [p].) Minot Collection, *75*.
347. (8, S, 25 & 50, [p].) Minot Collection, *75*.
348. (12, S, 25 & 50, [p].) Minot Collection, 75.
349. (20, C, 250, good, [i].) Brödel, Collection, 83, 91, *96*.
350. (15, C, 10, good, [t].) Brödel Collection, *82*, 83, 91, *95*, 97, 98.
351. (12, C, 250, good, [i].) Brödel Collection, 83, 91.
352. (9, C, 10, fair, [t].) Brödel Collection, 83, 91.
353. (11, C, 10, good.) Brödel Collection, 75, *82*, 83, 91, *92*, *95*, *96*, *97*, 98.
354. (190.) Dr. Meyer, 83.
355. (113.) Dr. Blades, 83.
356. (150.) Dr. Myers, 83.
357. (17, S, 50, fair, [p].) Dr. Russell, *75*.
358. ([p].) Dr. Swett, Bangor, Me., 75.
359. (160,) Dr. Myers, 83.
360. (14.) Dr. Egbert, Washington, 75, 83, *84*.
361. (young ovum, [t].) Dr. Egbert, Washington, 75, 83.
362. (39.) Dr. Rosencranz, 75, 83.
363. (23.) Dr. Rosencranz, 75, 83.
364. (16, S, good, [p].) Dr. Merrill, Stillwater, Minn., *75*, *84*.
365. (14, S, 50, good. [p].) Dr. Pohlman, Bloomington, Ind., *75*.
366. (9, S, 25 & 50, [p].) Dr. Pohlman, Bloomington, Ind., *75*.
367. (T, [t], [p].) Dr. Hunner, *75*, *84*.
368. (20, S, 20, poor,) Dr. Lamb, Washington, 83, 91, 96.
369. (T, [t], [p].) Prof. Brödel, 75.
370. ,S, [a].) Dr. Harrison, *26*.
371. (6.6, S 10, good.) Prof. Brödel, *71*, 83, 91, *92*, 98.
372. (7, T, 10, good.) Prof. Brödel, 83, 91.
373. (31, T, 20, good, [♂].) Prof. Gage, Ithaca, N. Y., 75, 83.
374. (7,) Prof. Gage, 83.
375. (13, S, 25 & 50. [p].) Prof. Gage, 75, 83.
376. (4,) Prof. Gage, 83.
377. (15.) Prof. Gage,
377a. (T, [p].) Dr. Crawford, Cedar Rapids, Iowa, 75.
377b. (104.) Dr. Crawford, Cedar Rapids, Iowa, 83.
377c. (52.) Dr. Crawford, Cedar Rapids, Iowa, 83.
377d. (30.) Dr. Crawford, Cedar Rapids, Iowa. 83.
378. ([t], [p].) Prof. Brödel, *75*.
379. ([p].) Dr. Myers, *75*, *84*.
380. (7. 5.) Dr. Wegefarth, 83, 91.
381. (63.) Dr. Lehnert.
382. (23, S, 50, good, [i].) Prof. Brödel, 81, 82, 83, 91, 96, 97.
383. (7. T, 10, good.) Prof. Brödel 83, 91, 98.
384. (2, T, 10, fair.) Dr. West, Bellaire, Ohio, 75, 83, 91.
385. Dr. Simpson, Pittsburg, Pa.
386. (9.) Dr. Birley, Thurmont, Md.
387. (8, T, 20, fair.) Prof. Brödel, 83, 91.
388. (9, S, 25, poor.) Dr. Pohlman, Bloomington, Ind., 75, 83, 91.
389. (8, S. 20, good, [t].) Dr. Castler, 75, 83, 91.
390. (15.5, S, 20 & 50, good, [t], [i].) Prof. Brödel, 83, 91, *95*, *96*.
391. (2, T, 10, good.) Dr. Pearce, Albany, N. Y., 75, 83, *87*, *88*, *89*, *90*, 91, *94*, *96*, 98.
392. (95.) Dr. Ballard, 83.
393. (6.) Dr. Wentz, Hanover, Pa., 83.
394. (90.) Dr. Blades, 83.
395. (T, 50, [p].) Dr. Pearce, Albany, N. Y., 75.
396. (T, 20, [t], [p].) Dr. Castler, *75*, *84*.
397. (8, T, 10, good.) Prof. Brödel, *82*, 83, 91, 97, 98.
398. (5, S, 20, [p].) Bardeen Collection, *75*.
399. (4, S, 20, [p].) Bardeen Collection, *75*.
400. (3.5, S, 20, [p].) Bardeen Collection, *75*.

401. (5.5, T, 20, [p].) Bardeen Collection.
402. (4, [p].) Dr. O'Shaughnessy, New Canaan, Conn. 75.
403. (27.) Dr. Russell, 75, 83.
404. (17, T, 40, poor.) Bardeen Collection, 91.
405. (24, S, 40. good.) Dr. Wentz, Hanover, Pa., 83, 91.
406. (13, S, 20, good.) Dr. Crawford, Cedar Rapids, Ia., 83, 91, *92*.
407. (4, T, 40, poor.) Dr. Davenport, Canandagua, N. Y.
408. (T, [p].) Dr. West, Bellaire, Ohio.
409. (16, T, 20, good.) Dr. West, Bellaire, Ohio, 83, 91, 97, 98.
410. (24.) Dr. West, Bellaire, Ohio, 83.
411. (80.) Dr. Girdwood, 83.
412. (140.) Dr. Girdwood, 83.
413. (5, T, 20, good, [p].) Dr. Stevens, 82.
414. (6, T, 10, good, [p].) Dr. Laughlin, Hagerstown, Md.
415. (T, 20, [t], [p]. Dr. Castler.
416. (9.) Dr. Lamb, Washington.
417. (32.) Dr. Elting, Albany, N. Y.
418. (T, [t], [p].) Dr. Castler.
419. (5, T, fair, [p].) Dr. West, Bellaire, Ohio.
420. (15, C, 20, fair.) Dr. Flexner, Louisville, Ky.
421. (T, [p?].) Dr. Wells, Hartford, Conn.
422. (9, C, 40, good, [t].) Brödel Collection, 91.
423. (15.2, T, 50, good.) Brödel Collection, 82, 91, 97, 99.
424. (17.2, T, 50, good, [i].) Brödel Collection, 82, 91, 97, 99.
425. (1, T, 50, fair, [p].) Brödel Collection.
426. (10.) Brödel Collection.
427. (100.) Dr. Wentz, Hanover, Pa.
428. (37.) Dr. Lamb, Washington.
429. (T, [p].) Dr. Dunn, Chicago.
430. (T, 30, [t], [p].) Dr, Castler.
431. (18.5, S, 20, good, [t].) Dr. Griffith, 91.
432. (18, S, 20, good.) Dr. Chambers, 91.
433. 3, T, 20, [p].) Dr. Lamb, Washington.
434. (15.) Dr. Knapp.
435. (41.) Dr. Conradi.
435a. (T, [p].) Dr. Conradi.
436. (3.5, T, 20, [p].) Dr. West, Bellaire, Ohio.
437. (23, S, 50, poor, [p].) Dr. Scholl.
438a. (95, ♂.) Johns Hopkins Hospital.
438b. (100, ♀.) Johns Hopkins Hospital.
439. (140.) Dr. Cullen.
440. (2.5, T, 50, good, [p].) Dr. Miller, Hagerstown, Md.
441. (2.3, T, 50, good, [p].) Dr. Haller, Davenport, Iowa.
442. (6, C, 50, poor.) Dr. Richardson.
443. (12.) Dr. Grant.
444. (89.) Dr. Simpson.
445a. (60, [p], chorion.) Dr. Fewsmith, Newark, N. J.
445b. (85, [p], chorion.) Dr. Fewsmith, Newark, N. J.
446. (8.5, S, 50, good, [p].) Dr. Morse, Boston.
447. (12, S, 20, fair.) Dr. Glidden, Danville, Ill., 91.
448. (52, S, 25–100, good, [t], [i].) Brödel Collection, *96*, *97*.
449. (34, S, 10–100, good, [t], [i], [♂].) Dr. Cullen, 91, *96*.
450. (18, S, 50, good, [p].) Dr. Girdwood.
451. (3.5, S, 20, good, [p].) Dr. Senior, Syracuse, N. Y.
452. (9, S, 40, poor.) Prof. Brödel, 91.
453. (23, S, 20, fair,) Dr. Lusk, New York, *96*.
454. (T, [p?].) Dr. MacCallum, New York.
455. (24, T, 30, fair.) Dr. MacCallum, New York.
456. (19, [t].) Brödel, Collection.
457. (62, [i].) Brödel Collection.
458. (54, [t], [i].) Brödel Collection.
459. (82.) Dr. Wentz, Hanover, Pa.
460. (21, T, 40, good [i].) Dr. Cullen, *96*.
461. (20.) Dr. Miller, Madison, Wis.
462. (20.) Dr. Lamb, Washington.
463. (3.9, T, 10, good.) Dr. Merrill, Stillwater, Minn.
464. (26.) Dr. Tredway, Punxsutawney, Pa.
465. (15, S, 50, fair, [p].) Dr. McComas, Oakland, Md.
466. (4, T, 40, fair, [p].) Dr. Rohlfing, St. Louis.
467. (9.) Dr. Rohlfing, St. Louis.
468. (T, [p].) Dr. Jackson, Pittsburg, Pa.
469. (3, T, 50, good, [p].) Dr. Jackson, Pittsburg, Pa.
470. (3, T, 10, good,) Dr. Mitchell, Elkton, Md.
471. (70, [p].) Dr. Poska, Philbrook, Mont.
472. (T, [t], [p].) Dr. Cullen.
473. (75.) Dr. Carpenter.
474. (72, [i].) Dr. Russell.
475. (15.) Dr. Bowen, Mt. Washington, Md.
476. (T,) Dr. Hunner.
477. (5, T, 20, good, [p], [t].) Dr. Miller, Porterville, Cal.

478. (22.½, [t].) Dr. Miller, Porterville, Cal.
479. (80, [i], [t].) Dr. Cullen.
480. (84.) Dr. Baier, Minneapolis, Minn.
481. (57, [i], [t].) Dr. Cullen.
482. (44, [i].) Dr. Morse.
483. ([p].) Dr. La Mont, Canton, Ohio.
484. (96, T, 40, good, [brain], [i], [t].) Dr. Cullen.
485. (13, [corpus luteum].) Dr. Hunner.
486. (4, T, 10, good,) Dr. Cullen.
487. (11 ?), [t].) Dr. Slocum, Wilmington, N. C.
488. (T, [p], [t].) Dr. Hunner.
489. ([p].) Dr. Luetscher.
490. (113, T, 30, fair, [medulla], [i].) Dr. Evans.
491. (8 mo, T, 40, good, [medulla, tissues].) Dr. Evans.
492. (16.8.) Dr. Beitler, Halethorpe, Md.
493. (34,) Dr. Lehnert.
494. (45.) Dr. Lehnert.
495. ([p], [t].) Dr. Davidson, Easton, Md.
496. (18, [t].) Dr. Lee, New London, Conn.
497. (43, [t].) Dr. Tobie, Portland, Me.
498. ([p].) Dr. Hunner.
499. (17, [p].) Dr. Arthur.
500. (9.) Dr. Miller, Porterville, Cal.

Total 533.

February, 20, 1911.

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RETIREMENT OF PROFESSOR BURT GREEN WILDER

After a service of forty-two years (1868–1910) Professor Wilder retired from active service in Cornell University. During the present academic year (1910–11) he has put the department records, material and museum in such shape that they will be of the greatest service in the future. At the end of this college year, at the age of seventy, he will leave Ithaca and reside in Brookline, Massachusetts, his boyhood home.

In organizing the Cornell University in 1867–68 it seemed to Andrew D. White, the first president, that provision should be made in its faculty for instruction and investigation in the natural sciences. It was his firm belief that it was the right and the duty of every educated man to possess a knowledge of nature, and especially a knowledge of his own structure and functions, and personal hygiene; hence provision was made in the new university for instruction in those subjects; and for a teacher, Louis Agassiz and Asa Gray recommended to President White, Burt Green Wilder.

In preparation for this work of creating a great department from the foundation up, Professor Wilder had had the best training then available in the elementary studies. He had served as a surgeon in the army from 1862–65. In this stern school of war, where often the needs were overwhelmingly great and the means limited, he had learned to make little go far. He had also learned the power of organization, and the necessity for discipline. In his college work and professional training in the Lawrence Scientific School and the Harvard Medical School, he had come under the inspiring influence of those great teachers and still greater men, Asa Gray, Oliver Wendell Holmes, Jeffries Wyman and Louis Agassiz.

To university teachers of the present day with luxurious quarters, numerous assistants and preparators, and abundant apparatus and material, it ofttimes seems a hardship to attend to the administrative duties of a department, even with the aid of a stenographer. But in starting with the new institution, Dr. Wilder was his own stenographer, preparator and assistant. If he had any assistance it was from students who were especially interested, and they received little or no pecuniary compensation. He started literally at the bottom; his office and laboratory—for he had a laboratory from the beginning—were in basement rooms now used for storing tools, etc.; and instead of a limited field, he had the whole of zoology, and the whole of anatomy, physiology and hygiene. Facilities were very meagre to start with, but they were soon created. As stated above, he had a laboratory in which students came in direct contact with real things from the beginning. He believed

that human anatomy—the best known then as it is to day of the anatomy of any animal—was a subject which would form one of the best factors in a biological training of the future as it had in the past. He knew from abundant experience, too, that for the physician a chance to study some part of human anatomy while he was studying comparative anatomy would give a broader outlook on medicine, hence human anatomy was included as a part of his laboratory instruction. He realized very keenly, also, from practical experience, how inadequately physicians were prepared to meet the demands put upon them, and very early (1869) there was established a full four years' course in natural history, especially adapted for those intending to become teachers or physicians. Somewhat later (1880), hoping to appeal to a larger number, there was established a two years course 'preparatory to medicine,' in which the original four years preparatory course was represented by the absolutely essential branches. It might be said in passing that this two years preparatory course almost invariably became a four years course for the students who entered it. Here then was the beginning, or one of the first beginnings of the movement for the better education of physicians, and the consequent improvement of medical schools in our country. Besides attending to the instruction in lecture courses, and in the laboratory, to say nothing of administrative duties, Professor Wilder was a teacher by example as well as by precept. He not only taught laboratory work, but he did his investigations before us, for his private laboratory was the general laboratory where we all worked, and if we ever became weary and thoughtless, his tireless efforts before our very eyes gave us a new sense of our opportunity to work.

The special interest of Professor Wilder was the philosophical significance of anatomy, and the subtle characters which show relationship and homology. To him there was always a fundamental plan somewhere hidden, and to find and comprehend this plan fascinated him.

The educational museum which he built up contains hundreds of specimens and dissections which bring out especially the relationship of animals and their structural plan. The fullest use of these has always been made to illustrate the lectures, and to impress fundamental ideas by concrete examples.

In the almost universal interest in the nervous system at the present time few know that with a kind of prophetic insight Professor Wilder saw that in the progress of anatomy and physiology the nervous system was to play the most important part. In 1870–71 he gave lectures in comparative neurology, and in 1875 vertebrate neurology became an established course in the university, and was continued by him until his retirement.

He believed most profoundly that if there were ever to be a true correlation found between the brain and character of the individual, the brains of people whose life and character were well known must be studied.

So convincing were his arguments that many intelligent people made provision that such use was to be made of their brains after their death,

and already eleven such specimens are in the Cornell collection. Besides these special human brains there are many others of all sorts and conditions of men, and a very large number from different animals, making nearly two thousand specimens in all.

In his work in neurology Professor Wilder became convinced that one of the greatest bars to the understanding of the nervous system, and indeed of all anatomy, was the ponderous, often conflicting nomenclature. He gave much time to a reform in this respect, and while his simple intelligible and consistent nomenclature has not been generally accepted yet the course of evolution is gratifying for what could not be ushered in all at once is coming in slowly and surely by the law of the 'survival of the fittest.'

In tracing the history of Professor Wilder's original department, four special aims seem to have been dominant: (1) to give the best possible elementary instruction to beginning students, and no pains were too great to accomplish this end; (2) to encourage those especially interested to do advanced work, and to undertake the investigation of special problems; (3) to combine the study of human and comparative anatomy so that those aiming to become physicians could most intelligently and successfully pursue their later medical studies; and (4) the establishment of independent departments with the growth of the university.

How completely this fourth aim has been realized during his active service is shown by the fact that the work carried on by the original department founded in 1868, is now represented by seven independent departments each with a full professor at the head. It is true that this development is as natural as it is necessary in the progress of education in our country; but what redounds to Professor Wilder's credit is that he deliberately made ready for these buds to grow, and when the time came, helped them in every way to separate from the parent stem and establish a vigorous and independent existence, without a thought apparently that in so doing his own importance might thereby be lessened.

As a teacher, Professor Wilder always inspired his students with the profound belief that the subject he was teaching was of supreme importance, and that the truth about this subject, as about every subject, was what was worth knowing; and that no pains, however great, were too much to devote to the discovery of this truth. He exemplified before his students from day to day by his own tireless efforts how deep in him was this belief, and that this belief was the guiding principle of his life.

How well he impressed his pupils with the love of science, and passed over to them the inspiration received by him from Gray, Holmes, Wyman and Agassiz, is attested by the distinguished men all over the country who, at the end of his twenty-fifth year of service (1893), collaborated in the presentation of a volume of scientific monographs written especially for the occasion—The Wilder Quarter Century Book—following the Festschrift plan of honoring a beloved professor in Germany.

The farewell to give him on leaving the department over which he has presided so long, might be fittingly expressed by slightly modifying the final passage of the dedication of the Quarter Century Book: "May the future of the department be presided over by those with the same unselfish devotion, high ideals, and the power to inspire both by teaching and by example."... ....

SIMON H. GAGE

INTERNATIONAL COMMISSION ON EMBRYOLOGICAL NOMENCLATURE

At the third session of the Second International Congress of Anatomists held in Brussels on August 10, 1910, Professor Minot demonstrated clearly in an address the necessity of a reform in embryological nomenclature. He recommended the appointment of an international commission to undertake the work. This was discussed by Professors Waldeyer, von Bardeleben, Eternod and Minot. Professor Waldeyer suggested that the Commission have a general secretary and Professor von Bardeleben nominated Professor Mall for this office, who was then elected by the Congress. In addition the following members of the Commission were appointed: Professors Brachet (Brussels), Bryce (Glasgow), Eternod (Geneva), Hill (London), Hubrecht (Utrecht), Keibel (Freiburg), Mall (Baltimore), Minot (Boston), Nicolas (Paris), and Romiti (Pisa). Upon the motion of Professor von Bardeleben the Commission was empowered to name alternates and to coöpt new members, as, for example, a philologist.

Professor Mall, who was not present at the meeting, finds that he is unable to serve as general secretary and has resigned this office in favor of Professor Minot. Nine of the members of the Commission approve of this change, which therefore places Professor Minot at the head of the Commission as general secretary.

BOOK REVIEW

LOCALISATION MOTRICE ET KINESTHÉSIQUE. LES NOYAUX MASTICATEUR ET MÉSENCÉPHALIQUE DU TRIJUMEAU CHEZ LE LAPIN. By Edouard Willems. Le Névraxe, vol. 12, pp. 1–220, 1911.

A monograph upon the motor nuclei and branches of the nervus trigeminus of the rabbit has just appeared from the physiological laboratory of the Institut Solvay, Brussels, whose results will be of interest to anatomists in several diverse fields.

The central functional localization of the motor branches of the trigeminus is carefully elaborated on the basis of chromatolysis of the cells of origin of the nerves supplying the several muscles belonging to this group after destruction of these nerves, and special attention is directed to the hitherto unsolved problem of the functional significance of the mesencephalic root.

The number and localization of all of the cells of the principal nucleus (nucleus masticatorius) which are functionally connected with each of the muscles innervated by the trigeminus were determined and the sum of the cells thus experimentally located was found to equal almost exactly the total number of cells in the intact nucleus.

Different neurologists have expressed almost every possible opinion regarding the significance of the mesencephalic root and nucleus of the fifth nerve, and the conflict of opinion could hardly be resolved so long as its peripheral relations remained unknown. The author comments on the fact that its nucleus lies in the sensory lamina of the nervous system and that its neurones resemble in internal structure and type of internuncial connections the sensory type of nerve cells more closely than the motor type, though in some respects they are unique. In the rabbit these fibers join the motor root and are distributed with the muscular branches. This is shown by chromatolysis of cells in the nucleus after section of most (but not all) of the individual muscular branches. The rate of chromatolysis in the mesencephalic nucleus is not the same as that of the principal nucleus and there is no evidence of a localized representation of separate muscles in the former, such as was found in the latter. Since all of the muscular branches are also represented in the principal motor nucleus, it is assumed that the mesenphalic root supplies sensory fibers to the muscles. This accords with Johnston's views, save that Johnston traces the mesencephalic fibers into the sensory root of the trigeminus and apparently regards them as reaching a cutaneous distribution, instead of serving the muscle sense exclusively, as Willems teaches. That some of these fibers may pass

through the sensory branches to the skin has not been disproved by Willems, for only about one half the total number of cells of the mesencephalic nucleus were involved in chromatolysis in his experimental destruction of the muscular branches of the trigeminus, and the connections of the remainder are still to be determined. These observations, however, are said to be incomplete and we are promised at a later time another report upon the mesencephalic nucleus, in which it is to be hoped that the question of cutaneous distribution of fibers of the mesencephalic root will be decisively determined.

The first part of the paper is followed by an enumeration of the number of fibers found in each of the muscular branches of the nerve, the number of central cells related to these several branches, the weights and histological characteristics of the individual muscles supplied by them and an extensive discussion of these statistics. The details of this examination cannot be summarized here, but a few of the general conclusions may be mentioned.

The observations show that the diameters of the nerve fibers are not dependent upon their length, nor do they bear any simple relation to the functional activity of their muscles. Stress is laid upon the fact that each muscle with its related nerve has an individuality of its own, and that this individuality is in part the result of secondary modifications in the muscles. For instance, an increase in the size of a muscle occurring in the ontogeny after the neuroblasts have ceased to multiply must result in a relative diminution in the number of central neurones per gram of muscle weight. And since the motor neurones cannot increase in number, there results an increase in the volumes of their cell bodies and in the thickness of their fibers.

The author does not discuss in this connection several well-known peculiarities of the peripheral nerves which have an obvious bearing upon the functional significance of fiber caliber, such as the fact that the different great functional systems of peripheral nerves tend to exhibit tolerably constant fiber characteristics wherever found in vertebrates (thus the fibers of the lateral line system are coarse, the visceral motor pre-ganglionic fibers are fine, etc.) and the fact that the sensory nerves of largest calibre (the lateral line nerves of fishes) have very small nerve cell bodies. The conditions underlying the individuality of various fiber systems are certainly very complex and Willems has made an important contribution by the isolation of one of these factors. His paper contains many valuable data and discussions which cannot be summarized here.

C. J. H.

AN INSTANCE OF PANCREATIC BLADDER IN THE CAT

M. DRESBACH

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ONE FIGURE

In the January, 1910, number of the Anatomical Record, W. S. Miller calls attention to the few recorded observations which have been made upon the occurrence of pancreatic bladders. These apparently anomalous structures have been seen only in Felis domestica, and but rarely. The pancreatic reservoir bears, when fully developed, the same anatomical relation to the pancreas that the gall bladder does to the liver, and doubtless functions in the same way, that is, by acting as a reservoir in which the secretion accumulates until it is required for digestion. At any rate, this view is supported by the facts detailed later in this paper in the description of the author's specimen.

Seven other examples of this structure have been recorded so far. Mayer described one in 1815, Gage one in 1879, and Miller a total of five between 1904 and 1910.[1] The specimen which forms the subject of this paper was found in a full-grown female cat. After being etherized for another purpose, its abdomen was opened for inspection and there was noticed a cystic structure lying adjacent to the gall bladder. Later, after the nature of the cyst was apparent, a careful dissection of it was made, its relations established, photographed and sketched, its histologic structure studied, and the contents of the cyst examined.

[1] Since publishing his last article, Professor Miller has found two more of these bladders in the cat.

ANATOMICAL RELATIONS

This bladder was somewhat pear-shaped, its diameters being 2 and 2.5 cm., the capacity equaling that of the gall bladder approximately. It lay slightly to the left of the midline attached to the gall bladder and caudad of it (see fig. 1). Close inspection showed that these two reservoirs were very intimately associated, but were completely separated, the line of division being distinctly marked off by the color of the two. Furthermore, careful examination revealed no opening from one to the other. A duct, equal in size to the ductus communis choledochus, could be traced from the pancreatic bladder to the duodenum, which it entered by a peculiar arrangement to be described presently. This cystic duct entered its cyst at an oblique angle, the opening being 2 mm. wide and quite patent.

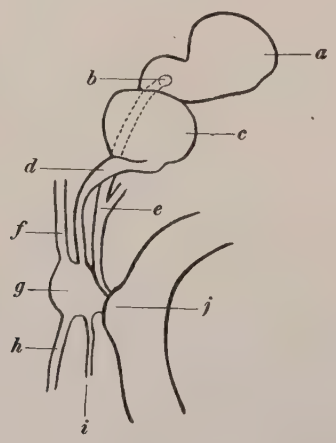

Fig. 1 Diagram to show the relations of the pancreatic bladder. Approximately one-half normal size; *a*, gall bladder; *b*, orifice of the cystic bile duct; *c*, pancreatic bladder; *d*, duct of pancreatic bladder; *e*, common bile duct; *f*, axial branch of the cauda pancreatis; *g*, cavity, or sinus, into which the cystic and pancreatic ducts empty; *h*, axial branch of the caput pancreatis; *i*, ductus accessorius; *j*, swelling of the ampulla of Vater, in the duodenum.

On tracing the tube towards the intestine, it was found to lie for the most part ventrad of the common bile duct. At the point where the ductus communis choledochus and ductus

pancreaticus ordinarily enter the duodenum there was found a unique variation, adjacent to the ampulla and embedded in pancreatic tissue. This variation consisted of an enlargement or sinus into which entered four ducts. An idea of the arrangement can best be gained from the diagram. One of the ducts was that from the pancreatic reservoir; two were the divisions of the ductus pancreaticus (Wirsung's), coming from the splenic and duodenal portions of the gland; and the fourth was either the ductus accessorius (Santorini's), or simply an extra duct draining a small portion of the pancreas near the ampulla of Vater. From this peculiar cavity, or common point of union of these various ducts, a single, very small channel led into the duodenum, through the ampulla, along with the common bile duct.

As far as the writer has been able to determine, this mode of termination of the cystic and pancreatic ducts is quite unique. In Mayer's case the cystic duct joined the trunk of the ductus pancreaticus, and Professor Gage found the same mode of termination of the cystic duct in his specimen, except that it divided near its termination, sending the larger branch to the gastro-splenic division of the duct of Wirsung, and the smaller branch to the common trunk of this duct. Miller, in his articles of 1904, 1905, and 1910, describes two types of union of the cystic and pancreatic ducts. In one of his cases the cystic duct terminated in the gastro-splenic division of the ductus pancreaticus, while in the other four cases it joined the duodenal division, the junction in all five cases being within a few millimeters of the main trunk of the ductus pancreaticus.

HISTOLOGICAL FINDINGS

The specimen and adjacent structures were fixed in 10 per cent formalin, hardened in alcohol, sectioned in paraffin and stained with haematoxylin and eosin. Some sections were also stained especially for muscle, elastic, and gland tissue. It was found that the microscopic structure was essentially like that of the gall bladder and its duct. There could be distinguished mucous, muscular and serous coats. The mucosa was consid-

erably less folded and had fewer glands than that of the gall bladder, and its epithelium was columnar and laid down upon a well defined basement membrane. The nature of the glands could not be determined. The plain fibers of the muscular coat were arranged in interlacing bundles, the direction of which was quite irregular.

A section was made through the partition separating the pancreatic and gall bladders, at a point (x in fig. 1), which revealed that they were covered by a common peritoneum.

A cross section of the duct showed that it was made up of the same coats as the bladder. Its muscular coat was well developed, the fibers being mainly circular and especially numerous in the muscularis mucosae. In the mucosa were a good many longitudinal muscle fibers. Tubular glands could occasionally be seen embedded deeply. They were not true mucous glands; further than this nothing can be said about them.

Contents of the bladder

Before the specimen was dissected it was opened, the contents withdrawn into sterile tubes and examined for digestive enzymes. Unfortunately, a towel wet with 10 per cent formalin had been laid over the exposed viscera before the nature of the sac was recognized. However, some evidence of enzymes was obtained. The fluid, about 2 cc. in quantity, having been proved to be sterile, a portion of it was put into a weak starch solution. In the course of a few hours the starch disappeared. As formalin does not interfere with the iodine test for starch, and as there were no bacteria, it seems fair to conclude that amylase was present. No evidence of proteolytic or other enzymes could be obtained, doubtless because of the formalin.

THE ORIGIN AND FUNCTION OF PANCREATIC BLADDERS

In his last paper Miller discusses briefly two hypotheses as to the origin of these structures. He points out that Heuer, in his work upon the pancreatic ducts of the cat, records an

observation that is suggestive. Heuer described an anomalous condition of the pancreas consisting of a band of pancreatic tissue extending along the ductus choledochus, the band in one case being very narrow and terminating in an expanded end near the gall bladder. As Miller states, it is conceivable that this outgrowth of pancreatic tissue could undergo degeneration in such a way as to become a duct with a distal enlargement forming a bladder. A more probable view, he thinks, would be: "that the ventral anlage in place of being double, may in these cases be bilobed, either from the beginning or as a result of fusion, one of the lobes having given rise to the caput of the pancreas, and the other to the bands of pancreatic tissue described by Heuer, or to the pancreatic bladders." According to this view then, these bladders would arise from true pancreatic tissue.

Another explanation suggested by F. T. Lewis is that they are cases of subdivided hepatic diverticulum, that is: "They are cases of double gall bladder, emptying into a subdivided cystic and common bile duct. The inferior subdivision (pancreatic bladder) has lost its connection with the liver, but has retained its connection with the ventral pancreas."[2] In his latest discussion of the embryology of the liver and pancreas (see references below) Professor Lewis has given the evidence upon which he bases his conclusion, which is further supported by an observation by Miller, who discovered a double gall bladder in a cat which was a full brother to one of the animals possessing a pancreatic bladder described by him in 1904. Both interpretations may be defended, but it is evident that a satisfactory settlement of the point at issue cannot be obtained until a thorough study has been made in the embryo of the cat.

The statement was made earlier in this paper that these bladders doubtless serve as reservoirs for pancreatic juice. While the author has evidence that enzymes were present in his own specimen, it may well be doubted that these cysts always contain true pancreatic juice. There is nothing in the

[2] Personal communication to the writer.

literature to show that a careful study has been made of this point, which, in as much as it deals with the possibility of an unusual function in connection with the pancreas, is quite as important as the mode of origin of the structure under discussion.

In the introduction, the writer supplements Professors Gage and Miller in calling attention to the rarity of these bladders. It is interesting to note that Professor Miller alone has seen seven, five of which he has described; and it is also very suggestive that three of his specimens were found in cats from the same farm. One of these cats had a full brother at a neighboring house, and this cat furnished the third pancreatic reservoir observed by him that year. There is strong evidence in these cases, therefore, that the cysts were inherited structures. The writer suggests that it would be interesting to attempt to obtain a race of cats possessing these bladders by breeding experiments with the near relatives of the one in which a pancreatic bladder is found. At any rate, it certainly would be worth while to make a practice in various laboratories of having the abdomens of cats, and other animals, opened whenever possible, in order to determine whether or not a pancreatic bladder be present. For physiological experiments, these cysts, if they were true reservoirs for pancreatic juice, would be most useful, as it would be very easy to convert them into permanent pancreatic fistulae, an operation of considerable difficulty under ordinary circumstances.

The author is indebted to Professors S. H. Gage and F. T. Lewis and Dr. W. S. Miller for suggestions during the preparation of this paper.

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AN INTERPRETATION OF GROWTH CURVES FROM A DYNAMICAL STANDPOINT

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Generally speaking, organic growth may be considered as an increase in volume. This increase in volume is usually associated in turn with an increase in mass. The growth process is accomplished by means of interaction with external agencies. However, sooner or later an individual reaches such a stage that under similar external conditions no more increment is added or it is so slight that subsequent changes may be totally neglected; in other words, the individual has reached the limit of growth. We also know that under normal conditions, external agencies cannot induce any individual to grow beyond a certain limit; for instance, cow's milk cannot induce a newly born rat to grow to the size of the young cow. Therefore the limit of growth at any stage depends on something beside the external agencies, and must be due to fundamental differences in the constitution of the germ cells of different species. In other words, a fertilized ovum of the rat is potentially different from that of the cow.

This fundamental difference in the composition may be interpreted as the 'inherited character.' This would mean then that a different amount of potential growth energy is already stored within the fertilized ovum according to the different species, before any growth has actually taken place. For instance, the maximum brain weight of the albino rat is approximately 2 grams, while that of man is approximately 1400 grams. Thus under normal conditions, the albino rat possesses an energy or a capacity of brain growth which is equivalent to 2 grams, while that of man is equivalent to 1400 grams. This energy must be stored

within the respective germ cells potentially since external agencies fail to modify this relation. This ability to attain final maximum is here called the 'growth energy.'

It is true that this energy diminishes gradually but at a fixed rate as growth proceeds, and at the end this energy is either zero or negligibly small. Meantime inversely, as the growth energy diminishes, an individual gains an increment of weight. In other words, the growth energy is used in order to convert various forms of matter into the mass which compose the body. Thus the mass so formed is an index of the amount of growth energy transformed.

We now introduce an abstract term 'work' in contrast with the growth energy and hereafter we measure the amount of work done by the transformation of the growth energy in place of determining the amount of mass formed by the assimilation of the foods, etc. This manner of thinking simplifies our investigation.

Using these terms, our problem of growth may be stated in a much simpler form; that is the growth phenomena may be considered as a gradual transformation of growth energy to work done in forming the mass which composes the body. We now wish to determine what law, if there is any, governs in any individual the rate of transforming the growth energy into work? This seems to me the fundamental problem to be investigated.

About a hundred and fifty years ago Maupertuis (1751) tried to show that the principle of least action was the one which best exhibited the wisdom of the creator. This law of Maupertuis is now mathematically expressed in the following form

$$\text{Action} = \int mvds \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

or the action is a space integral of the momentum, with the definition that subject to the condition that total energy is assigned, the mode in which a conservative system passes from one configuration to another is such that the action is a minimum or $\delta A = G$.

The law of Maupertuis just given is the one which the present writer wishes to apply in order to solve the problem given above. That is we assume that under normal conditions the growth energy

is transformed into the work with least loss of energy. In other words, we assume that during growth, energy is most economically utilized.

In order to make the above statements clearer, let us consider a graphic representation of the growth of the brain in weight with respect to the body weight and assume that the curve is a continuous pathway of a point from the initial to the final position. The theory asserts that provided the sum of the potential and kinetic energy is constant, the pathway from one point (say, brain weight at birth) to another (say, final brain weight) is such that the action is least.

In other words, in order to reach another limit a point follows such a pathway that the least amount of energy is expended.

As has already been shown, the capacity for growth diminishes as time goes on, nevertheless we notice an increase in mass. Thus we have the following simple but important relation during growth, which is; at any time the sum of the total increment made or the work done and the amount of capacity remaining is constant. This of course satisfies the initial condition that the sum of potential and kinetic energy is constant, if we refer the amount of mass formed to the amount of kinetic energy gained and the amount of potential energy lost to the amount of growth energy lost.

We are now ready to test whether our growth curve satisfies Maupertuis' law of least action.

Consider first that the following integral is to be minimized

$$u = \int \psi(x)\,\phi(p)\,dx, \text{ where } p \text{ stands for } \frac{dy}{dx} \quad \ldots\ldots\ldots (2)$$

Then from the principles of the calculus of variations we obtain

$$\delta u = \int \psi(x)\,\phi'(p)\,\delta p\,dx + \tfrac{1}{2}\int \psi(x)\,\phi''(p)(\delta p)^2\,dx$$

$$= \psi(x)\,\phi'(p)\,\delta y - \int \frac{d}{dx}\left\{\psi(x)\,\phi'(p)\right\}\delta y\,dx + \tfrac{1}{2}\int \psi(x)\,\phi''(p)\,(\delta p)^2\,dx.$$

Since the limits are fixed, the term which is outside the integral sign vanishes. Then we have

$$\frac{d}{dx}\left\{\psi(x)\,\phi'(p)\right\} = o$$

or

$$\psi(x)\,\phi'(p) = c$$

Thus δu now reduces to

$$\tfrac{1}{2}\int \psi(x)\,\phi''(p)\,(\delta p)^2\,dx$$

Let us consider the equation

$$\psi(x)\,\phi'(p) = c \qquad (3)$$

This gives p in terms of x, from which y can be obtained. There will thus be two constants, arising from the solution of equation (3) which must be determined in order to have the curve pass through the given limiting points.

In the equation: Action $= \int mv\,ds$, we notice that $ds = \phi(p)\,dx$ and mv is in general a function of x or $mv = \psi(x)$. Therefore in order that $\delta A = o$ we must have from the above (3)

$$\psi(x)\,\phi'(p) = c$$

or

$$\frac{dy}{dx} - \frac{c}{\sqrt{\{\psi(x)\}^2 - c^2}} = o \qquad (4)$$

This differential equation may be solved at once if we know the nature of $\psi(x)$. As long as an independent variable is expressed by an arbitrary function, the number of the forms of $\psi(x)$ which satisfy this equation is unlimited. This does not necessarily mean that the number of formulas which represent the growth curves is unlimited, but it means that we must select some form of the function which is suitable to each particular case.

If our assumption that the growth phenomena can be interpreted by the theorem of Maupertuis was correct, the formula of the growth curve must be included in one of the functions which satisfies the differential equation (4). It thus remains to determine such a function as satisfies both the equation (4) and the conditions given by the growth data.

As one case I will take up the growth of the brain in weight and this may represent any growth data which satisfy the same conditions as are imposed in the case of the brain weight.

We have ample evidence that the increment of the brain in weight is inversely proportional to that of the body weight and therefore the total increment will be the sum of an increment at any given value of the body weight to the initial brain weight which itself is inversely proportional to the body weight or

$$\text{Total amount of increment} = k\left(\frac{1}{x}+\frac{1}{a}\right)$$

where x represents a given body weight, a an initial body weight and k a constant.

We may take this value for $\psi(x)$ in equation (4) and seek the function which renders the integral minimum.

The integral which has to be minimized is clearly the following

$$u = k\int\left(\frac{1}{x}+\frac{1}{a}\right)\sqrt{1+\left(\frac{dy}{dx}\right)^2}\,dx \qquad (5)$$

Thus for the condition that $\delta u = 0$ we must have at once from (4)

$$y = \int \frac{ca\,x\,dx}{\sqrt{k^2(x+a)^2 - c^2a^2x^2}}$$

Let

$$\lambda = \frac{ca}{k} \text{ and } A = (1-\lambda^2)$$

Then

$$y = \lambda\int \frac{x\,dx}{\sqrt{A\,x^2+2ax+a^2}}$$

Change

$$x+\frac{a}{A} = Z.$$

Since

$$\sqrt{A\,x^2+2ax+a^2} = \sqrt{A\left(x+\frac{a}{A}\right)^2 + \frac{a^2(A-1)}{A}}$$

We have

$$y = \lambda\int \frac{\left(Z-\frac{a}{A}\right)dZ}{\sqrt{A\,Z^2+\theta}} \qquad \text{where } \theta = \frac{a^2(A-1)}{A}.$$

This integral may be divided into two terms, thus

$$y = \lambda\left[\int \frac{Z\,dt}{\sqrt{A\,Z^2+\theta}} - \frac{a}{A}\int \frac{dt}{\sqrt{A\,Z^2+\theta}}\right]$$

The first term reduces to

$$I_1 = \lambda \int \frac{Z\,dt}{\sqrt{A\,Z^2+\theta}} = \frac{\lambda}{\sqrt{A}} \sqrt{Z^2+\frac{\theta}{A}} \quad \ldots\ldots\ldots\ldots (6)$$

while the second reduces to

$$I_2 = -\frac{\lambda\, a}{A} \int \frac{dZ}{\sqrt{A\,Z^2+\theta}} = -\frac{a\,\lambda}{A^{\frac{3}{2}}} \log\left(Z+\sqrt{Z^2+\frac{\theta}{A}}\right) \ldots\ldots (7)$$

since

$$y = I_1 + I_2$$

we have

$$y = \frac{\lambda}{\sqrt{A}} \sqrt{Z^2+\frac{\theta}{A}} - \frac{a\,\lambda}{A^{\frac{3}{2}}} \log\left(Z+\sqrt{Z^2+\frac{\theta}{A}}\right)$$

Restoring the values of Z, λ, A, and θ we have

$$Y = \frac{c\,a}{k\sqrt{1-\frac{c^2a^2}{k^2}}} \sqrt{\left(x+\frac{a}{1-\frac{c^2a^2}{k^2}}\right)^2 - \frac{c^2a^4}{k^2\left(1-\frac{c^2a^2}{k^2}\right)^2}}$$

$$- \frac{ca^2}{k\left(1-\frac{c^2a^2}{k^2}\right)^{\frac{3}{2}}} \log \left\{ \left(x+\frac{a}{1-\frac{c^2a^2}{k^2}}\right) \right.$$

$$\left. + \sqrt{\left(x+\frac{a}{1-\frac{c^2a^2}{k^2}}\right)^2 - \frac{c^2a^4}{k^2\left(1-\frac{c^2a^2}{k^2}\right)^2}} \right\} + c_2 \quad \ldots\ldots (8)$$

In order to simplify, let us make the following substitutions

$$\alpha = \frac{ca}{k\sqrt{1-\frac{c^2a^2}{k^2}}}$$

$$\beta = \frac{a}{1-\frac{c^2a^2}{k^2}}$$

$$\gamma^2 = \frac{c^2a^4}{k^2\left(1-\frac{c^2a^2}{k^2}\right)^2}$$

we have

$$y = \alpha \sqrt{(x+\beta)-\gamma^2} - \alpha\beta \log\left\{(x+\beta)+\sqrt{(x+\beta)^2-\gamma^2}\right\} + c^2 \quad \ldots (9)$$

This is then the function (y) which satisfies the condition, and therefore, if our assumptions are correct, it ought to represent adequately our growth curves. Before going on to test this point, let us see to what simpler forms this equation reduces.

Suppose the value of c in equation (8) is very small but not zero and the two other constants k and a are moderately large. Then c^2 becomes very small and since k and a are moderately large, all terms which contain square of c may be neglected. Then we have

$$\alpha = \frac{ca}{k}; \quad \beta = a; \quad \gamma^2 = o$$

Thus (6) now reduces to

$$y = \alpha (x+\beta) - \alpha\beta \log \{ 2 (x+\beta)\} + c_2$$

$$= \frac{ca}{k} (x+a) - \frac{ca^2}{k} \log (x+a) + c_2 \ldots\ldots\ldots\ldots (11)$$

where

$$c_2 = (c_2 - \alpha\beta \log 2)$$

If we change the position of x into $x+\beta$ and write the new value of x as X, we have

$$y = \alpha X - \alpha\beta \log X + c_2$$

or

$$y = a + bx + c \log x \ldots\ldots\ldots\ldots\ldots\ldots (12)$$

Again in (11) if we consider that c is still smaller we may also neglect $\frac{ca}{k}$ but remembering that $\frac{ca^2}{k} > \frac{ca}{k}$ equation (11) reduces to

$$y = -\frac{ca^2}{k} \log (x+a) + c_2$$

which may be written

$$y = a + b \log (x+c) \ldots\ldots\ldots\ldots\ldots\ldots (13)$$

The equations (12) and (13) are thus the particular cases of the more general equation which is given above (8). Some readers will at once recognize these two formulas just given since these are the formulas which are already extensively used for graduating observed growth curves.

Pearl ('07) who also used the formula of type (12) expresses his opinion in the following words: "It is so good, in fact, that it is apparent that this logarithmic curve is the analytical expression of the manner in which the changes in the shape of the egg of no. 183 occurred." The present writer also used the formula (13) for numerous kinds of growth data and always obtained most satisfactory results. In fact, anyone who uses the logarithmic formulas of either type will have the same opinion as Pearl had.

It is now clear that our suspicion in regard to the nature of the formulas was quite justified since these were the mathematical expression of the fact of the growth; that is the formulas are the mathematical expression of the fact that growth is accomplished with the least loss of energy.

It is quite clear that formulas (12) and (13) can be easily obtained from the solutions of the following differential equations respectively:

$$\frac{dy}{dx} = \frac{k}{x+c},$$

$$\frac{dy}{dx} = k\left(\frac{1}{x} + \frac{1}{a}\right)$$

However such equations do not give us any indications of their biological significance. So far as a mere fitting of the curves is concerned, many other convenient forms may be taken with equal advantage. Thus there is no more need to test the adequacy of the formula to represent the growth curves, since numerous applications have been made with satisfaction and already published.

I therefore put forward the following provisional definition of growth:

An organism during growth tends to form the greatest amount of mass with least loss of growing capacity.

It is my purpose to test this conclusion in future from various standpoints. At any rate, as a working hypothesis, the law of Maupertuis seems to me to be very promising for the solution of various growth problems as well as numerous biological questions.[1]

[1] See Wilder D. Bancroft: A universal law, Science, N. S. vol. 33, no. 840, pp. 159–179, 1911.

Our discussion on the normal rate of growth lead us to conclude that the animals tend to grow at maximum rate with least loss of growth energy. The question arises naturally concerning the interpretation when the animals do not reach their usual final maximum as will be seen when animals grow under abnormal conditions or when the form of the curve actually found is changed from that of the normal series. This question will be cleared up if we examine the properties and genesis of the formula.

It is clear that in any particular case there is only one curve which can pass through the two given points under the conditions imposed on page 377, though the number of curves which can be drawn from the formula is unlimited. This means that so long as the data can be represented by any one of the lines drawn from the formula, spanning the interval between the two given points, we are always justified in concluding that the animal has made the best possible growth, since this is the only line which can satisfy the conditions.

Suppose the growth of the brain in weight was considerably retarded by some experimental process and as a consequence the brain weight did not (possibly will not) reach its maximum, nevertheless, if our logarithmic curve can describe its growth we must conclude—though we are utterly ignorant of the fate of the remaining growth energy—that so far as the interval between the two points is concerned, the animal has made its best growth with respect to the brain weight, since this is the only line that can be drawn under the conditions which satisfies our fundamental proposition [equation (5)].

If, on the other hand, the growth had been modified to such an extent that our logarithmic formula fails completely, then it is evident we shall be unable to state whether or not the animal has made the best growth without further investigation. This point must be kept in mind since under the last conditions, though our logarithmic formula fails to fit the data, nevertheless the curve actually found may still satisfy the theorem of Maupertuis under some other conditions than those which we have imposed in the present paper.

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THE ANATOMY OF A DOUBLE CAT

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FOUR FIGURES

The literature of teratology contains many descriptions of monsters among the domestic animals. Of these cases, two or three, that most closely resemble the present example, will be described.

Pilcher ('80) describes a single-headed, double-bodied, female pup which died at birth. The body fusion here extended to the umbilicus. It had a single umbilical cord, and a 'compound' liver. The stomach and the first two-thirds of the small intestine were single, then the intestine bifurcated and was double to the end. The urogenital systems were independent and complete for each body. There were two perfect sets of lungs. The hearts were fused. There was no trace of duplicity in the head though the necks were distinct. The thorax was compound, the sternum and ventral ends of the ribs of each side being so reflected and fused with the corresponding parts of the other as to form one cavity with forty-eight ribs. There were four complete anterior appendages, and the posterior appendages and pelves were distinct and perfect.

Dareste ('52) describes a cat in which the division took place at the base of the tail, so that there were two normal tails and four normal hind legs. The specimen being badly preserved no dissection, except that of the skeleton, was made.

Gurlt ('32) describes, among numerous other domestic animals, a cat with a single head and two bodies. This cat had two anterior and four posterior appendages. The rectum, caecum, and caudal part of the ileum were double; the rest of the intestine, the stomach, the trachea, the thyroid, and the heart were single. The right kidney was in the right side of the body, the left kidney in the left side. There were two aortic arches, two pancreases, and two livers, the right liver being incomplete. The right lung was rudimentary.

EXTERNAL ANATOMY

Nothing is known of the history of the cat which is about to be described; it was found, in a jar of alcohol, by the author, on taking charge of the department.

Judging from its size and general appearance it was probably a product of a more or less normal parturition. Its color is almost pure white, not a single black hair being visible. Its length from tip of nose to base of either tail is 12.5 cm. Its weight, after being preserved for several years, at least, is 70 grams.

Fig. 1 A dorsal view of a cat monster.

Dorsal view (*fig. 1*). This view of the head and neck is perfectly normal. At the base of the skull, between the ears, is a patch of faintly reddish-brown hairs. In the region of the shoulder girdle the separation of the two bodies begins. The compound character of the appendage here represented is shown by the partially double manus, and by the longitudinal groove in the integument that covers this appendage.

Each manus is more or less normal, though, of course, somewhat twisted because of its close relation with the other. From this aspect it would appear that the compound appendage is composed of the left leg of one body and the right leg of the other body.

Fig. 2 A ventral view of the cat shown in fig. 1.

The two bodies, of which the left, as seen in this view, is slightly the larger, are united by their ventral aspects, as far caudad as the region of the umbilicus. Two umbilical cords are present; they arise about 2 mm. apart and lie in a plane mediad between the two bodies, rather than, as might be expected, in a plane passing in a dorso-ventral direction through the two bodies. Of the rest of the fetal appendages nothing is known.

From their point of complete separation each of the bodies is apparently quite normal, the four hind legs and two tails being essentially symmetrical.

Ventral view (*fig. 2*). This view, also, of the head and neck has quite the normal appearance. In fact, from this aspect, the appearance is that of a normal kitten as far caudad as the region just back of the forlegs.

The forelegs have the appearance of being the normal appendages of the, in this view, right body, but examination of the skeleton shows that these two legs probably do not belong to the same body, and that the compound leg, as was mentioned in connection with fig. 1, is probably formed by a partial fusion of the right foreleg of one body with the left foreleg of the other body.

In the posterior thoracic region both bodies are so twisted as to bring their ventral aspects towards each other.

The general appearance of the monster, from this view, is as though the right body were the one belonging to the head, while the left body seems to spring from the right thoracic region of the main body. Owing to the similarity in size, and to the similar torsion of the two bodies, this appearance is not very marked.

So far as could be determined externally, the sexes were the same, female, and subsequent dissection proved this to be the case.

INTERNAL ANATOMY

After photographing the monster, from the two aspects shown in figs. 1 and 2, it was opened along the mid-ventral line. This dissection is shown in fig. 3.

The tissues were found to be rather soft, but they were sufficiently well preserved to show gross structure. No attempt was made to study the muscles.

As seen in the figure, the appearance of the neck and thorax is about normal, except that the latter is unusually wide at its posterior end. The oesophagus and stomach are single, and are apparently of normal size and structure. The trachea, heart, and lungs are also apparently normal for a single individual, except that the heart is rather larger than would be expected in a kitten of this age.

Owing to their softness and to the uniformity of the color of the tissues it was difficult to determine the outlines of the spleen and pancreas, but they are apparently normal for a single individual.

The liver, *l*, is single and of fair size; the outlines of its lobes could not be determined definitely because of poor fixation.

Extending caudad from beneath (dorsal to) the liver, to the left of its median plane, is seen the coiled intestine of the ileo-jejunal region, *i.j.* The intestines were drawn away from the body and sketched in that position. This single region of the intestine, after extending through several coils, in a more or less normal way, divides, suddenly, at right

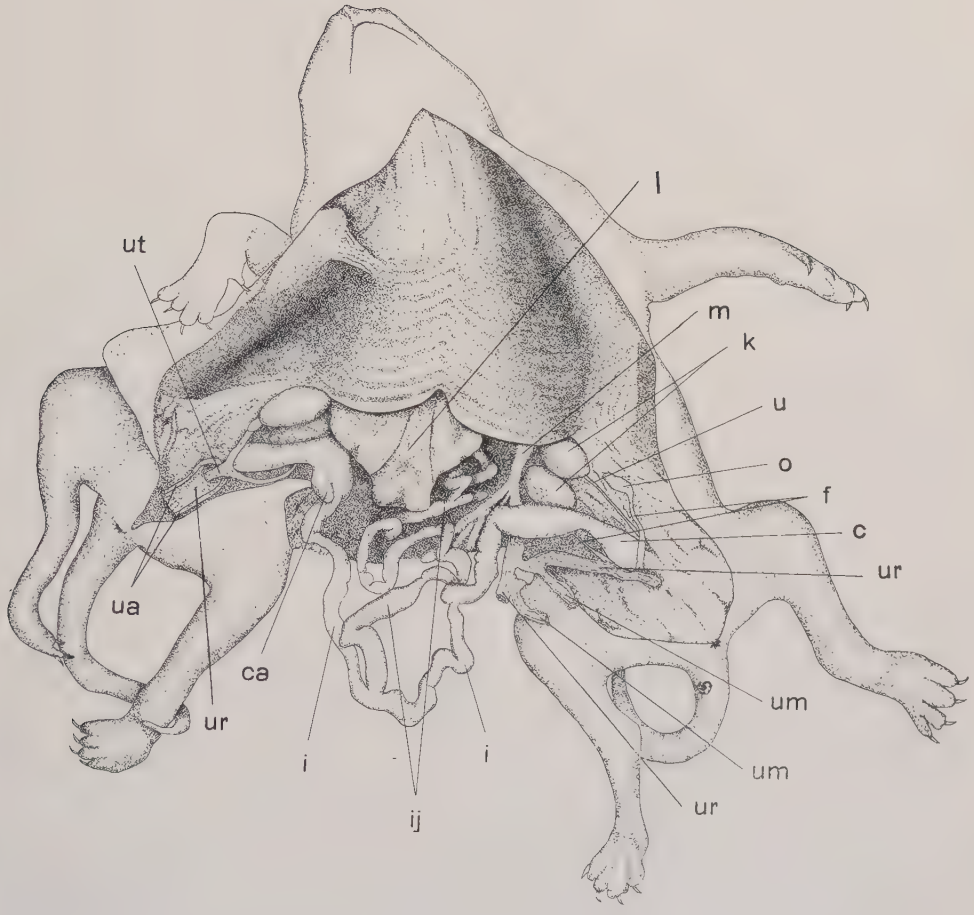

Fig. 3 A dissection of the cat shown in figs. 1 and 2; *c*, colon; *ca* caecum; *f*, Fallopian tube; *i*, ileum; *i*, *j*, ileo-jejunum; *k*, kidney; *l*, liver; *m*, mesentery; *o*, ovary; *u*, ureter; *ua*, umbilical arteries; *um*, umbilical cord; *ur*, urachus; *ut*, uterus.

angles, into two distinct ilea, *i*. Each ileum is about 5 cm. long and extends towards the median plane of its respective body to join the apparently normal colon, *c*. At the junction of the ileum with the colon is seen a well developed caecum, *ca*, shown in the figure only in the left body. The colon is shown in each body only to the point where it is covered by the uterus, *ut*.

The urogenital organs are complete for each body. The kidneys, *k*, are all of about the same size, and are normally located. The ureter of the left kidney of the right body is shown at *u*.

As was noted above, both bodies are females. The ovaries, *o*, Fallopian tubes, *f*, and uteri, *ut*, seem quite normal in structure and position.

As was also noted above there are two distinct umbilical cords, *um*. In opening the body wall the umbilical vein (or veins) was broken, so that it could not be determined whether one or two veins were present inside the body of the animal. In the body wall the cords are closely united, but each sends a distinct urachus, *ur*, to the pelvic region of its respective body; the urachus of the left body had to be cut in order that the two bodies might be laid flat for dissection. In the right body only one umbilical artery could be demonstrated; it lies under the urachus in the view drawn and so is not shown in fig. 3. In the left body a distinct umbilical artery, *ua*, may be seen on each side of the urachus, and each may be traced around the uterus, *ut*, and rectum to its union with the blood vessels of the kitten.

THE SKELETON

Owing to the state of preservation it was not practicable to clean the skeleton completely, but enough of the flesh was removed to show the skeletal peculiarities of the specimen. No attempt was made completely to free the ribs and vertebrae of flesh, and it was impossible fully to clean the joints of the appendages without great danger of injury to the skeleton.

Fig. 4 represents a camera sketch of the skeleton thus prepared, as seen from the dorso-lateral aspect. The skull presents no abnormalities, nor do either of the bodies caudad to the lumbar region; these structures, then, will need no description here, except to note that the body on the right is somewhat heavier than that on the left. In these respects the skeleton resembles that of the puppy described and figured by Pilcher ('80); but the cervical region, also, is here normal, while in his figure it is double and of unusual length.

As in Pilcher's puppy, there is here a single thorax, formed by the fusion of the two sets of ribs in a plane median to the two bodies. The plane of fusion of the ribs on the side here shown is seen as a light streak, *s*, just to the right of the single median humerus; this streak should represent one of the sterna, or two halves of the two sterna involved in the fusion.

Although difficult to count with accuracy the number of ribs for each body is apparently normal.

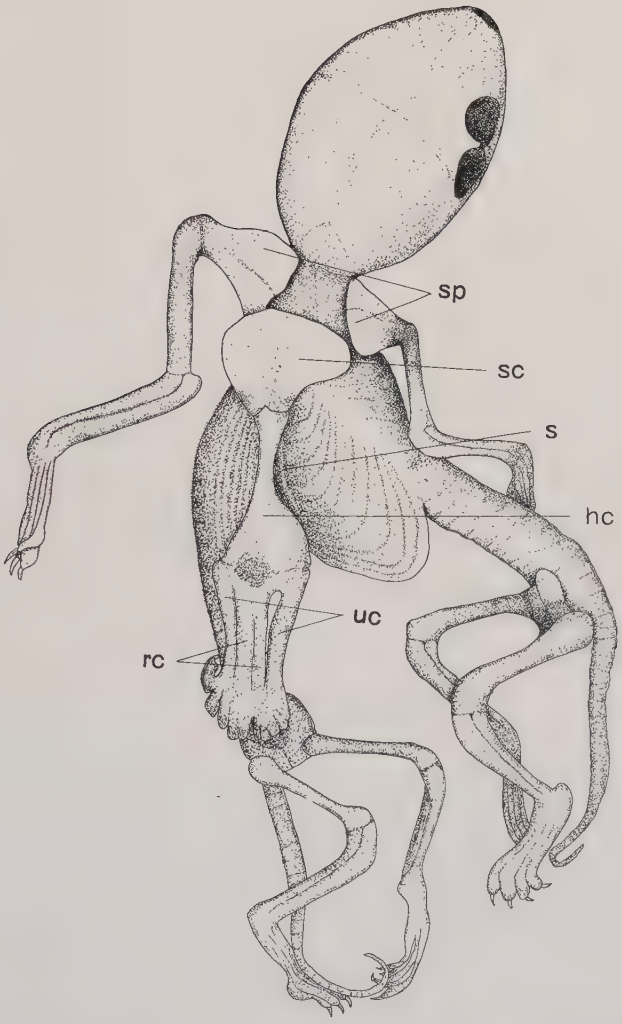

Fig. 4 The partially cleaned skeleton of the cat shown in figs. 1 and 2, drawn to show the gross anatomical features; *hc*, compound humerus; *rc*, compound radius; *s*, sternum; *sc*, compound scapula; *sp*, paired scapulae; *uc*, compound ulna.

Owing to the mode of fusion each spinal column is somewhat twisted, that on the right being the more so.

As seen from the opposite side (fig. 3) only two anterior appendages are visible, and these are quite normal in appearance; but, from the present aspect, a third compound appendage is in evidence.

The two symmetrical appendages are quite normal in structure and position in relation to the single head. They were dissected free and were drawn with the scapulae, *sp*, less closely applied to the neck and rather closer to the base of the skull than they were originally.

Attached to the anterior region of the thorax, in nearly the median plane of the figure, somewhat caudad to the paired scapulae, is seen the large unpaired scapula, *sc*. It is nearly twice as large as either of the other scapulae, and is almost bilaterally symmetrical. It is rather thick, and has a prominent, medially located spine, which is in contact caudally with the anterior end of a prominent spine on the compound humerus, *hc*.

This humerus, though of approximately the same length as the other two, is considerably thicker (not well shown in the figure) especially at its distal end, where two enormous condyles are seen with a deep depression between them. The above mentioned spine at its anterior end makes the dorso-ventral diameter of this end of the humerus considerably greater than the lateral diameter. As in the compound scapula the fusion of the two bones of which this humerus is doubtless composed, is complete.

The middle region of this appendage consists of two distinct, laterally placed, ulnas, *uc*, and a medial, compound radius, *rc*. The exact form of the articular surfaces for the elbow and wrist, owing to their softness and cartilaginous character, could not be determined.

The compound radius is formed by the partial fusion of two distinct bones. This fusion is complete at the proximal end, but is incomplete distally. The cartilages of the two wrists are apparently as closely joined as the individual cartilages of each wrist; and the digits, of which there are ten, are only indistinctly separated into two sets of five each; this separation is hardly as distinct as shown in the figure.

As was noted above, this entire appendage was covered by one fold of skin, though the double nature of the middle and distal regions was discernible through it.

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A METHOD FOR HANDLING CHICK EMBRYOS

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TWO FIGURES

It is a common experience to those working with chick embryos to have the membranes curl up in the killing fluid or the alcohols. To overcome this defect various devices have been employed.

Probably the most common method in use is the weighting of the edges of the blastoderm with pieces of glass or lead. Glass is rather difficult to manipulate in such small pieces and not infrequently slips from the forceps to tear the blastoderm or to destroy the embryo. For this reason weights are unsatisfactory especially for beginners.

Another method is to cut a ring of filter-paper large enough to encircle the embryo and a portion of the extra embryonic membranes, and then to press this ring down onto the blastoderm with the embryo in the enclosed space. There are at least two serious objections to this process. In the first place, if the paper adheres properly and the membranes have been stretched a little too much, the tissues will tear as they shrink in the reagents. In the second place there is no way of removing a fold in the membranes once the filter-paper has been attached.

The method which I use, and which my students use with the best of success, is also a filter-paper process. The egg is opened as usual in normal salt solution and then the embryo with a wide margin of embryonic membrane is removed to a watch glass. The tissues are now spread out, and all the water that can be easily extracted by means of a pipette removed. Pieces of filter paper, 2 x 4 mm. for twenty-four-hour embryos and larger for older chicks, are now touched to the edge of the blastoderm to which they adhere. It is necessary that the paper strips be dry when they come in contact with the membranes otherwise they will not stick satisfactorily. These bits of paper can now be used to pull the tissues about at will, and they will adhere sufficiently to the bottom of the watch glass to hold the membranes in a spread condition. The

filter paper pieces should be used in numbers sufficient to bring their edges almost together where they come in contact with the blastoderm.

After the tissues have been spread as much as desired, the killing fluid is put drop by drop onto the embryo until the contents of the watch glass are covered. The embryo may have a tendency to float, but when the paper becomes soaked the blastoderm with the filter paper can be pushed to the bottom where it will remain. In fig. 1 is seen an embryo prepared by the above process.

An embryo treated by this method is not removed from the watch glass until it is ready to mount or imbed. It can be carried through the running water wash and all the various reagents without the slightest danger. For sections the extra tissues may be cut from the embryo in the 95 per cent alcohol, but for whole mounts the trimming of the tissues should be done in the xylol. It is better to leave the paper strips attached to very young embryos (twenty hours and under), and to mount all together as shown in fig. 2. To mount an embryo of an early stage, a cover glass is seized by a pair of forceps and worked under the embryo until it is suitably arranged on the glass, then the cover glass with the embryo is lifted from the xylol and inverted onto a slide which has been prepared with a little balsam.

By the above method all wrinkling of the membranes can be avoided and at the same time the paper strips yield sufficiently to the necessary shrinkage to prevent any tearing of the tissues. Embryos as young as eight hours can be carried through by this process with success and very little trouble. On the whole this method has proved in every respect most satisfactory in our laboratory.

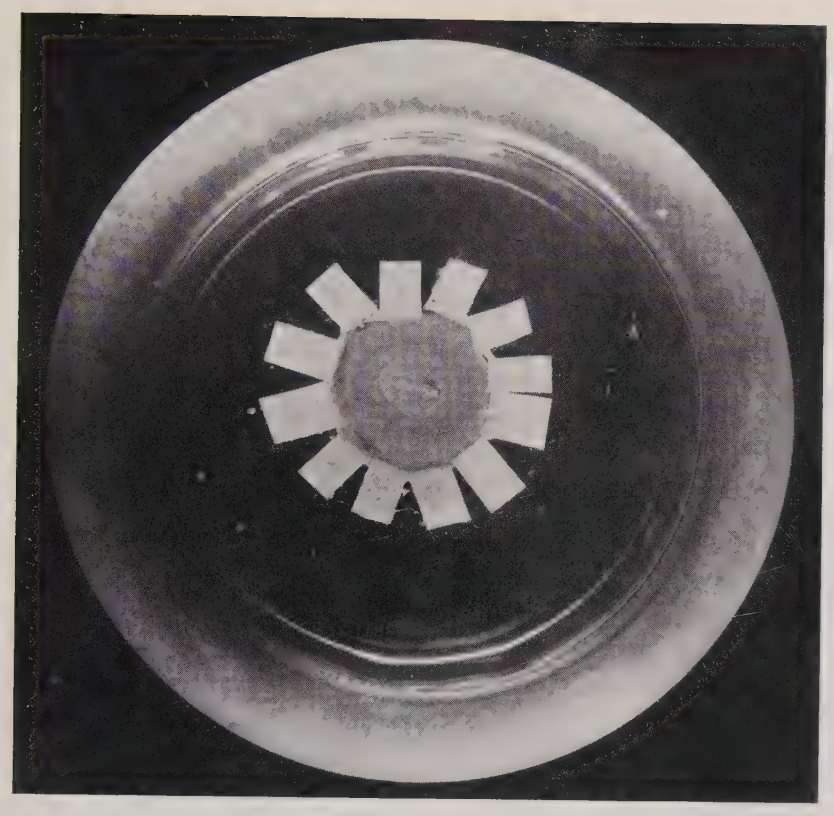

Fig. 1 Twenty-four-hour chick embryo in corrosive acetic spread out by filter paper strips.

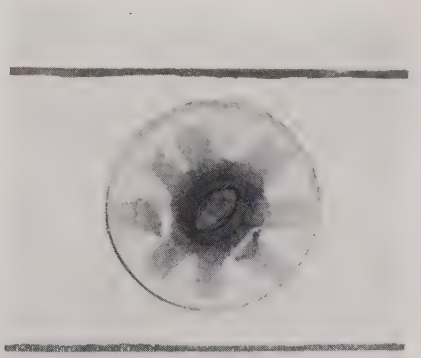

Fig. 2 Eighteen-hour chick embryo mounted with filter paper strips attached.

AN EXAMINATION OF METHODS USED IN THE STUDY OF THE DEVELOPMENT OF THE LYMPHATIC SYSTEM

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SEVEN FIGURES

Any study of the methods which have been applied to the solution of a problem will necessarily bring out a clearer picture of the development of the problem itself. In the work on the development of the lymphatic system there has been throughout a striving to obtain a view of a lymphatic plexus as a whole that is as it would actually appear in the living animal as well as an effort to reveal the picture from sections. The method of injection illustrates the effort to get the general picture, the stripping off of pieces of the skin, injecting its vessels under the microscope and making total mounts of these specimens shows again this effort which reaches its perfection in the observation of the entire system in a given area in the living form. It may seem hardly necessary to emphasize the advantage of using all possible methods, if not always in one's own work, certainly through understanding the value of the observations of others and the necessity of comparing and testing the limitations of different methods.

In this study I propose to follow first the development of various methods as far as they bear on the problem of the development of the peripheral lymphatics in amphibia, and secondly to present a test of the relative value of the known methods since the amphibian material offers the best available opportunity for such test.

There is coming to be a fairly general agreement among investigators as to the primary mode of origin of the lymphatic system. The studies of Sala on the chick, Miss Sabin and her pupils, G. Heuer and Baetjer, on the pig, and Miss Sabin on man, F. T. Lewis on the rabbit and on man, Huntington and McClure on the cat, Knower and Hoyer on amphibians, Mirzejewski on the chick, and Stromssen on turtles, appear to have established the fact that the lymphatic system is first differ-

entiated in the embryo by the transformation of venous plexuses, in certain well-defined regions of the body. This transformation is described as taking place by the coalescence of neighboring blood capillaries resulting in the formation of sacs, or hearts, which are the first recognizable lymphatics. Sala and Stromssen believe that the mesenchyme surrounding the capillary plexuses contributes cells to help form the endothelium of the lymph hearts, yet they present no convincing evidence for this view. Surely the balance of evidence favors the view that the first lymphatic endothelium to differentiate is derived exclusively from blood-vascular endothelium, by a direct transformation of the endothelium of the blood capillaries.

While this view as to the primary differentiation of the lymphatic system has almost the unanimous support of investigators, there is a striking disagreement as to the further development of this system. Regarding this there are three main views: (1) that the further development of the lymphatic system takes place by a continuance of this process of transformation and the addition of blood vessels; (2) that it is effected by means of the mesenchyme cells, which are transformed into lymphatic endothelium; and (3) that the lymphatic endothelium, after its primary differentiation from blood vessels in the form of sacs, or hearts, is a specific, independent structure, which gives rise to all the lymphatic endothelium of the body by a centrifugal invasive growth as the roots of a tree, or the ducts of a developing gland grow.

The first of these views, namely, that further development of lymphatics takes place by a constant addition of blood vessels, rests on slight evidence. There are three names associated with this view, S. Mayer,[1] F. T. Lewis[2] and McClure.[3] S. Mayer studied the transparent tails of living batrachian larvae. He observed that in addition to many non-blood-containing vessels there are many vessels through which blood cells pass only rarely or not at all, which have definite connections with the main vessels either through an open lumen or by solid processes. Mayer did not know whether these should be considered as blood vessels or lymphatics, for they have certain features which are characteristic of both systems. Hence he merely stated that there seems to be a close relationship between lymphatic and blood vessels without

[1] S. Mayer: Sitzungsber. der kaiserlichen Akademie der Wissenschaften, Wien, Abth. 3, Bd. 91 and 92, 1885.

[2] F. T. Lewis: Amer Journ. Anat., vol. 5, 1906.

[3] McClure: Anat. Anz., Bd. 32, 1908.

attempting to define the nature of this relationship. Mayer used comparatively crude methods in this study. The larva was anesthetized with curare and an electric current, and placed on a slide, with a cover slip resting on the part to be examined. The crudeness of the method is shown by the fact that he was unable to make more than two successive observations on the same larva because of the intense leucocytosis that appeared on the third day. By a much improved method, involving the use of chloretone as an anesthetic, and an upright chamber which practically avoids all mechanical pressure on the tail I have succeeded in making successive daily observations and careful records on the same growing larva for periods of weeks, which explain completely Mayer's statements.[4] The 'blutleeregefässe' which he describes are of two entirely distinct kinds. The one consists of the lymphatics which collect into the dorsal and ventral caudal lymph trunks. These are in no way connected with the blood vessels. The other set consists of blood vessels which, for one reason or another, have constricted to such an extent that blood cells cannot enter them. Several observers have shown that mechanical and electrical stimulation may cause a constriction of the endothelium of blood vessels, and both methods were employed in Mayer's studies. Again, as I have pointed out in a former paper, there is much reconstruction of the meshwork in a growing blood capillary plexus. While some capillaries increase to become arterioles or venules and others remain as capillaries, there are others which gradually grow narrower until they are too small to admit a blood cell. After a varying length of time the lumen of a vessel may be obliterated entirely to form a solid thread, which then breaks and retracts so that the capillary disappears entirely. Again, these capillaries respond very remarkably to slight circulatory changes, particularly in older larvae such as Mayer used. Thus large areas of blood capillaries may often be seen closely constricted with no blood cells passing through them. I have frequently seen such a condition persist for hours, to be succeeded by an active flow of blood cells through the same vessels by replacing the tadpole into fresh water or by changing the strength of the anesthetic. Under all these conditions the lymphatic vessels with their characteristic walls remain entirely distinct. It is certain that Mayer confused the two sets of 'blutleeregefässe.'

F. T. Lewis in reconstructing the lymphatics from serial sections in rabbit embryos, found isolated endothelial-lined spaces along certain

[4] E. R. Clark: Anat. Rec., vol. 3, 1909.

veins which he was unable to connect with the blood vascular system. In this same region in older embryos definite lymphatic ducts were found. While he refrains from making a positive statement, he says (p. 110), "Subsequently lymphatic vessels develop along the courses of the azygos and cutaneous veins, apparently from independent venous outgrowths." The origin of these isolated endothelial-lined spaces as found by Lewis in making reconstructions, still awaits satisfactory explanation. Reference will be made to them later.

McClure[5] studied serial sections of cat embryos by the method of reconstruction in wax. He concluded that the thoracic and right lymphatic ducts are formed directly from blood vessels. He states that buds grow out from the veins and are split off by a process of 'fenestration' to form a series of isolated spindle-shaped spaces. These later become confluent with one another and unite with a process from the jugular lymph sac to form a continuous system, connected with the veins only through the jugular sac. Inasmuch as McClure[6] had previously advocated with Huntington a different method for the development of these same lymphatics and as he subsequently[7] abandoned the view that they arise from transformed blood vessels and returned to his first view, namely that lymphatics are formed from extra-intimal as well as mesenchyme spaces, his work affords but little support to the blood vascular origin of the peripheral lymphatics.

The second view, that further lymphatic development is effected by means of a transformation of mesenchyme cells into lymphatic endothelium, has been proposed in various forms by a number of investigators, among whom may be mentioned Kölliker,[8] Billroth,[9] Virchow,[10] His,[11] von Recklinghausen,[12] Goette,[13] Budge,[14] Gulland,[15] Sala,[16] and most

[5] McClure: Anat. Anz., Bd. 32, 1908.

[6] Huntington and McClure: Anat. Rec., vol. 1, 1906-08.

[7] McClure: Verhandl. d. anat. Gesellsch., August, 1910.

[8] Kölliker: Annales des Sciences Naturelles, 3d ser., T. 6, 1846.

[9] Billroth: Entwickelung der Blutgefässe, Berlin, 1856.

[10] Virchow: Cellular pathology. English translation, Lippincott, Philadelphia, 1863.

[11] His: Zeitschrift für wissenschaftliche Zoologie, vol. 13, 1863.

[12] Von Recklinghausen: Die Lymphgefässe und ihre Beziehung zum Bindegewebe, Berlin, 1862.

[13] Goette: Die Entwickelungsgeschichte der Unke, 1875.

[14] Budge: Archiv für Anatomie und Physiologie, 1880 and 1887.

[15] Gulland: Journal of Pathol. and Bact., vol. 2, 1894.

[16] L. Sala: Richerche fatte nel Laboratorio di Anat. normal, Roma, 1900.

recently Huntington and McClure.[17] Kölliker, Billroth, Virchow, His and Goette supposed that the lymphatics, as well as the blood vessels, in the tail of the frog larva were connected with processes of mesenchyme cells, and that the growth of both the blood vessels and lymphatics takes place by the addition of these cells which are transformed into endothelial cells. It should be remembered that at this time many believed the mesenchyme cells to be hollow and that they formed the ultimate radicles of the blood and lymph vascular systems. Kölliker[18] later withdrew his support from this view, agreeing with those who found the blood vessels and lymphatics unconnected with mesenchyme cells. From numerous studies His came to believe in the view that lymphatics possess definite, independent walls. That lymphatics in in the tail of the frog larva are unconnected with the mesenchyme cells has been maintained by Remak,[19] Langer,[20] Hensen,[21] Rouget,[22] and myself, and would seem to be established beyond question in studies soon to be published, in which each individual mesenchyme cell in a selected area has been watched while a lymphatic sprout grew out among them and always remained independent. Von Recklinghausen's 'Saftkanälchen,' thought to be direct continuations of the lymphatics and blood vessels through irregular spaces among mesenchyme cells, have been abandoned.[23] Budge's work has been tested and discussed by Miss Sabin.[24] It is clear that he was dealing not with lymph vessels but with the extra-embryonal coelom.

The more recent advocates of the second view, Gulland, Sala, Huntington and McClure, have all based their conclusions mainly on studies of serial sections of embryos. Gulland found the earliest lymphatics in a sheep foetus $1\frac{1}{2}$ inches long. He states that they "arise by dilatations of pre-existing connective tissue spaces in the line of the greatest lymph flow." Sala finds the thoracic duct in the chick arising by the formation of *solid*

[17] Huntington and McClure: Amer. Jour. Anat., vol. 10, 1910. Huntington: Anat. Rec., vol. 4, 1910.

[18] Kölliker: Zeitschrift für wissenschaftliche Zoologie, Bd. 43, 1886.

[19] Remak: Archiv. für Anatomie und Physiologie, 1850.

[20] Langer: Sitzungs. d. k. Akad. d. Wissenschaften, Bd. 57, 1867, and Bd. 58, 1868.

[21] Hensen: Arch. f. mikr. Anat., Bd. 4, 1868.

[22] Rouget: Archives de Physiologie, T. 5, 1873.

[23] MacCallum: Johns Hopkins Hospital Bulletin, Jan. 1903.

[24] Sabin: Am. Jour. Anat., vol. 1, 1902. Cf. also Hochstetter: Entwickelungsgeschichte des Lymphgefässystem in O. Hertwig's Handbuch der verg. und exp. Entwick. der Wirbeltiere, Bd. 3, Abt. 2, 1906.

cords of mesenchyme cells, which later become hollowed out. Huntington and McClure who have most persistently advocated the second view, have studied principally the region of the thoracic duct in cat embryos. By studying numerous reconstructions of embryos of various stages, they conclude that the lymphatic channels are formed by the coalescence of *isolated spaces* which appear in the mesenchyme and that the mesenchyme cells become flattened out and transformed into endothelial cells. In their earliest publication they supposed this process to occur exclusively in the neighborhood of certain veins by the formation of extra-intimal spaces which coalesce to form lymph ducts and eventually replace the veins. More recently they modify this view and now state that this process may also occur in places at a distance from veins.

The third view, that peripheral lymphatics are formed by a centrifugal extension of preëxisting endothelium, will be referred to later.

In considering the evidence on which the first two views are based, it is obvious that they are dependent almost entirely on the result of studies of serial sections usually by means of wax-plate or of graphic reconstructions. Since the results are so divergent from those obtained by other methods, the question may well be asked whether any study of the growing lymphatic in serial sections is perfectly reliable. In fact, this question should be asked even if the various results were in accord. If it be found that all the lymphatic endothelium present at any period of development can be seen in stained cross sections and can be differentiated from blood vessels, perineural spaces and shrinkage spaces, then much may be expected from this method; if they cannot be surely and completely identified, we must accept with reserve the results obtained from an unreliable method.

A scrutiny of the publications of Huntington and McClure fails to reveal any crucial test of the reliability of the method employed, the extent to which it may be used accurately, or the criteria which they accepted in determining the nature of any structure. They find spaces in the mesenchyme at one stage of development and in certain regions. In later stages in these same places they find lymphatics and maintain that the latter have arisen from the former, though they give no convincing illustrations of the method by which the supposed transformation takes place. The fallibility of this reasoning and the unreliability of the evidence is shown by the fact that McClure, in studying practically the same region and the same material, has successively advocated three different views: first ('07), that the lymphatic ducts and vessels arise entirely from extra-intimal spaces; second ('08), that they are formed by

a transformation of blood vessels; and third ('10), that they arise from mesenchymal spaces either around the collapsing blood vessels or free from them. Since in the tadpole's tail the entire lymphatic system can be seen in the living larva, this material offers the best possible opportunity for testing the relative value of different methods. Starting with the living form which gives the vessels to the last tiny sprout, the vessels thus known can be injected, fixed and seen in total mounts, cut into serial sections and then reconstructed. Moreover, in the reconstruction the vessels are known beforehand, which gives the maximum of advantage and the results can then be compared with reconstructions of entirely unknown vessels. The results of this variety of tests with the original control from the living specimen will now be given in detail.

It was briefly indicated in a former paper that the transparent portion of the tail of the frog larva affords an excellent opportunity for testing the reliability of the method of reconstruction from serial sections and its possible limitations. The test was made in the following way. In the living larva all the histological elements, lymphatics, blood vessels, mesenchyme cells, wandering cells, nerves, pigment cells, may be seen with remarkable clearness. Of the identity of the lymphatics—seen and described many times in the living larva, in fixed and in injected specimens since their first discovery by Kölliker[25] in 1846—there can be no question. It is easy with the aid of chloretone and the upright chamber, previously mentioned, to make a careful high power (400 to 600 diameters) camera lucida drawing of all the lymphatics and blood vessels present over a selected area of the fin expansion in a living larva. This record of the structures in question as they exist in a normal living animal, serves as a control. The larva is now killed with corrosive acetic, or with Zenker's fluid, and is then passed through graded alcohols. While in alcohol it may be studied in toto in order that the effects of fixation may be noted. The tail is then cut into serial sections and stained in various ways and reconstructions are made to see whether it is possible to differentiate blood vessels from lymphatics in stained sections and finally to reproduce the picture obtained from the surface drawing made while the animal was alive. The injection method may also be tested, for after a control record has been made, the lymphatics of the

[25] See the previous references to Kölliker as well as Tarchanoff: Pflüger's Archiv, Bd. 9, 1874; H. Hoyer: Verhandlungen der Anatomischen Gesellschaft in Genf. 1905.

tail may be injected and the transparent tail may be studied in alcohol to determine whether the injection of the lymphatics is complete, partial or is extravasated. Moreover, the possibility at once suggests itself of using this object not only for testing the limitations of various methods which have been used, but for the developing new and improved methods. It may be through careful comparison of the same structures in life and after fixation that characteristics may be noted and criteria established which will be of service in the study of the lymphatics in regions which on account of the nature of the tissue can be studied only by means of injection or by reconstructions made from serial sections.

The results of a comparison between the living larva and the same specimen studied in toto in alcohol are as follows: The thin expansion of the tail, especially of the small larva of hyla pickeringii, reacts quickly to preserving fluids. Even when considerable care is used in passing through graded alcohols (5 per cent changes from 30 to 70 per cent, and 1 per cent changes from 70 to 80 per cent), there is always some shrinkage, since the larva shortens and the dorso-ventral width of the tail is diminished. The change in the thickness of the tail is extremely variable and often quite irregular in a given specimen, and may vary from the slightest diminution to a complete collapse, so that the two layers of epidermis are practically in apposition. It is not uncommon for one fin to remain approximately normal, while the other collapses completely. It is hoped that a method will be found which will eliminate this uneven shrinkage. When the fin expansion of the tail of a larva is studied with high magnifications in 70 or 80 per cent alcohol, it is found that the various histological elements may be distinguished nearly as accurately as in the living larva, and drawings of lymphatics and blood vessels before and after fixation agree most accurately. The lymphatics retain their characteristic walls with irregular thickness and numerous fine projections, although it is occasionally difficult to determine in the dead tail whether some of the finest processes belong to lymphatic or to mesenchyme cells. The diameter of the lymphatics is usually slightly diminished by fixation but the lumen is well maintained. Toward the tip the shrinkage is greatest, and often for a short distance there is complete collapse, so that a short terminal portion which had a lumen during life now looks solid. The blood vessels behave quite differently for while their lumina are sometimes maintained with slight diminution there is usually much constriction and very often a complete collapse for considerable distances.

A study of the wall of the lymphatic capillary in the alcohol specimen reveals a structural formation not to be seen in the living larva. The most favorable object for this observation was found to be a larva in which the tissues had reached a rather quiescent stage as the result of many prolonged daily treatments with chloretone. The lymphatics, when the larva was killed, were almost free from fine processes, and furthermore during the passage through graded alcohols there was considerable irregular shrinkage, some of the lymphatics becoming smaller while others became wider and shallower as if they had been partially flattened out. This latter change greatly aided the study of their structure for it furnished an almost flat instead of a sharply rounded surface.

In the living larva the wall of the lymphatic capillary is seen to be of irregular thickness. Much of it is extremely thin and delicate, while here and there at irregular intervals are nuclear thickenings. The limits of the nuclei cannot be distinguished, as the nuclei are surrounded by a finely granular area which extends for some distance longitudinally along the lymphatic in both directions, but principally toward the tip. When seen in profile the nuclear area has the shape of a section through a narrow elongated spindle. In the alcoholic specimen referred to the flattened capillary wall shows a much more elaborate organization (fig. 1). The nuclear areas with the granular perinuclear material are seen as during life and in addition there are long threads of protoplasm which pass as extensions

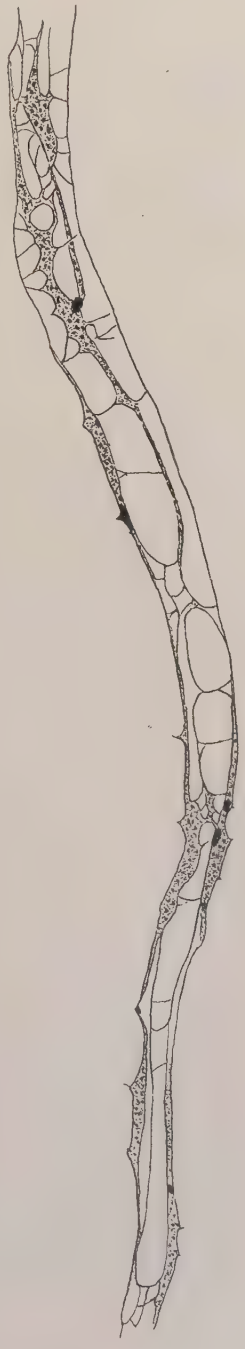

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Fig. 1 Lymphatic capillary from a total specimen of the tail of a hyla pickeringii larva in 80 per cent alcohol, unstained. Zeiss 2 mm. oil immersion. The larva had been anesthetized with chloretone for several hours daily for one month. It was killed with corrosive acetic (saturated aqueous corrosive sublimate + 5 per cent of glacial acetic acid). The large black dots represent pigment granules, the finely dotted areas contain nuclei.

of the perinuclear material to the next nucleus and sometimes well beyond it. There are also seen finer transverse threads as well as loops of endoplasm forming a basket-work structure within the outer hyaline exoplasm. In the fixed specimen it is indeed difficult to say certainly whether all the threads of this basket-work are in the wall or whether some of them belong to the surrounding mesenchyme cells. It can be definitely determined, however, that particularly the larger threads communicate directly with the granular area around the nucleus of the

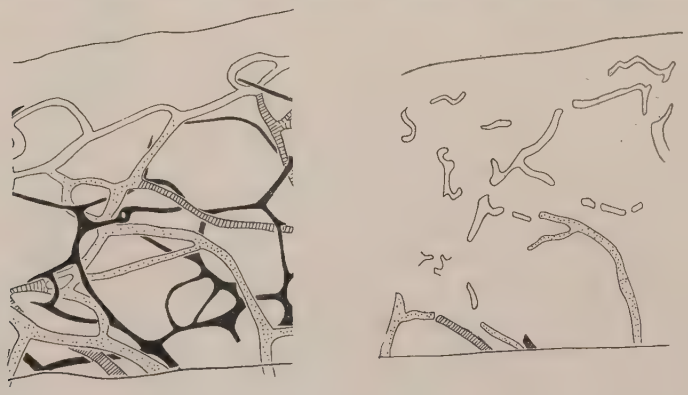

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Fig. 2 A drawing made from the tail of rana catesbiana during life. Arteries are striated, veins are dotted, blood capillaries are outlined and the lymphatics are black. Enlarged about 50 times.

Fig. 3 A reconstruction of the portion of the tail shown in fig. 2. The specimen was fixed in a mixture of corrosive-acetic and cut into sections 10μ thick. The sections were stained with hematoxylin and congo red and the camera drawings were corrected with a Zeiss 2 mm. oil immersion lens. The various vessels are marked as in fig. 2. Note that the lymphatic is shown only in the lower part of the figure and that the criteria for distinguishing vein and capillary are not sharp as in the living form.

lymphatic endothelium, while many of the smaller threads are branches of these. Furthermore, this structure agrees with what is seen in stained cross sections, which will be referred to later.

A study of serial sections of the tadpole's tail was undertaken to test the reliability of methods which have been used and upon which definite conclusions have been based as to the mode of development of the lymphatic vessels. Hence the technic employed in the first test was to simulate as nearly as possible the methods employed by those studying mammalian embryos. A camera lucida drawing was made of all the lymphatics and blood vessels present in a certain portion of the tail of

the living bull-frog larva to serve as a control. This is shown in fig. 2. The larva was then killed with corrosive-acetic, passed through graded alcohol 10 per cent at a time, imbedded in paraffin, and cut into serial sections 10 microns in thickness, which were stained with Delafield's hematoxylin and congo red. Congo red is a comparatively weak protoplasmic stain much as is orange-G used by Huntington and McClure. An attempt was then made to reconstruct from the sections these lymphatics and blood vessels, which are shown in fig. 2. The camera lucida tracings of successive sections were supplemented by a careful study with the oil immersion lens. The results are seen by a glance at fig. 3. It may be noted that practically the entire network of lymphatic capillaries of the region studied could not be seen in the serial sections. It was possible to trace only one branch from the ventral caudal lymph trunk, and that for but a short distance. The blood capillaries could be identified somewhat better than the lymphatics, but, as the figure shows, their reconstruction is far from complete. In many instances connections were lost, so that parts of a capillary known to be connected with the main system during life, appear in the reconstruction as isolated structures. Moreover, a differentiation of the blood vessel from the lymphatic was extremely difficult as the wall of the lymphatic merely appears but a little more faintly stained than the wall of the blood vessel. With this faint protoplasmic stain no satisfactory criteria for the differentiation of the two could be established. It will readily be seen that a method such as this which fails to show the presence of a considerable network of already formed lymphatic capillaries and which cannot be relied upon to reproduce the blood capillaries, is entirely inadequate as a method by which to attempt to study the mode of development of these lymphatics.

With the hope that more intense protoplasmic stains might make it possible to differentiate more definitely the lymphatics from the blood vessels, acid fuchsin and Mallory's connective tissue stain were tried. It was found that with both of these stains the endothelium of the lymphatics shows a characteristic structure which enables them to be recognized far better than is possible when the weaker protoplasmic stains are used. The observations were made principally on sections deeply stained with Van Gieson's (acid fuchsin and picric acid) mixture. With this stain the endothelium of the blood capillaries appears as a definite membrane, deeply and homogeneously stained, in which the nuclei can here and there be seen. Even when completely collapsed, so that the lumina are obliterated, it is still possible to recognize them with a fair

degree of completeness. The endothelium of the lymphatics shows marked differences from that of the blood vessels. It is much more delicate, so that it appears to be more faintly stained. Moreover, it is not homogeneous. When seen in cross-section it appears as a delicate membrane in which are granules of various sizes. On focussing up and down it is found that these granules seem to move up and down the wall. Nuclei are often seen, although in a section 10 microns thick no nucleus may be included. A longitudinal section of a lymphatic shows instead of granules a structure which is very like that described in the alcohol specimen (fig. 1), namely, fibrillae of varying thickness, which run longitudinally and transversely and which are thicker in the neighborhood of the nucleus. It is evidently these structures which give the granular appearance in transverse sections.

Aside from these two kinds of definitely-walled structures there are to be seen in sections the clear spaces in the mesenchyme without definite walls. They occur most often around the blood vessels, and are almost certainly to be interpreted as shrinkage spaces, or spaces caused by a retraction of the mesenchyme processes made possible by slight rents produced in the preparation of the sections. They are often seen around the caudal vein, and may sometimes be followed through several sections. Fig. 4 shows such a shrinkage space around the collapsed caudal vein. The well defined ventral caudal lymph trunk may be seen at a little distance from the vein. The similarity between this shrinkage space and the illustrations of 'extra-intimal lymphatic anlages' as pictured by Huntington and McClure is most striking.

With definite criteria established, let us see how completely it is possible to reconstruct the blood vessels and lymphatics. A larva of hyla pickeringii, 10 mm. long, was killed in Zenker's fluid and a drawing was made of the blood vessels and lymphatics in a portion of the fin expansion while it was in 70 per cent alcohol to serve as a control. This is shown in fig. 5. As has been mentioned, the blood and lymph vessels may be seen practically as well in the alcohol specimen as during life. The larva was imbedded in paraffin, cut into serial sections 10 microns thick, and deeply stained with Van Gieson's mixture. Drawings of each section were made with the aid of the camera lucida. As it was thought to be of interest to determine whether the oil immersion would prove to be superior to the dry lens in this study, two sets of corrections were made, one set with a 4 mm. dry lens and the other with a Zeiss 2 mm. oil immersion lens. The results of the reconstruction with the dry lens are shown in fig. 6. By comparsion with the control drawing (fig. 5)

it is seen that nearly all the blood vessels were found, though occasionally gaps appear where the vessel is continuous in the living animal. The attempt to reconstruct the lymphatics was less successful. Isolated portions appear in the reconstruction; these are connected in the living control. Frequently considerable portions of the lymphatics are lost entirely, particularly toward the tip, as fig. 6 shows. The results ob-

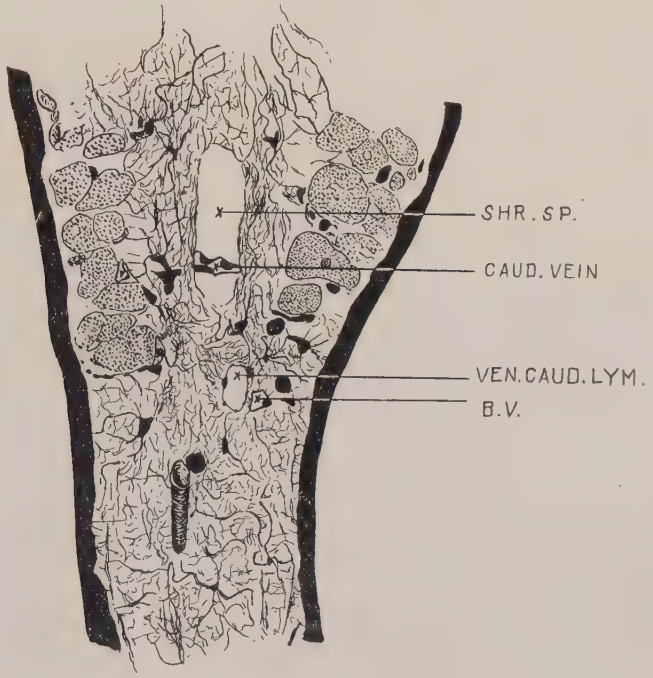

Fig. 4 Section of the tail of hyla pickeringii. The same specimen is shown in figs. 5, 6 and 7. Zeiss 2 mm. oil immersion. Enlarged 450 diameters. *BV*, blood vessel; *ven. caud. lym.*, ventral caudal lymphatic; *caud. vein*, caudal vein; *shr. sp.*, shrinkage space.

tained with the oil immersion lens are given in fig. 7. As may be seen, this lens carries us much further than does the dry lens, for many of the gaps are filled in. Still the reconstruction is incomplete since isolated portions appear and the tips are frequently lost. The complete lymphatic system as shown in fig. 5 could not be reconstructed under the most favorable conditions. Thus a careful testing of the method of

EXPLANATION OF FIGURES

Fig. 5 Drawing of the blood vessels and lymphatics in the tail of hyla pickeringii 10 mm. long. Blood vessels are outlined and the lymphatics are black. The tadpole was fixed in Zenker's fluid, passed through graded alcohol 10 per cent at a time to 70 per cent, one per cent at a time to 80, and 2½ per cent at a time to 100. Drawn while in 70 per cent alcohol.

Fig. 6 Reconstruction of sections of the tadpole shown in fig. 5 The specimen was cut 10 microns thick and stained intensely in Van Gieson's acid fuchsin mixture. The outline drawings were controlled with a 4 mm. lens.

Fig. 7 The same as fig. 6, except the outline drawings were controlled with a Zeiss 2 mm. oil immersion lens. It is easy to identify the same vessels in the three figures.

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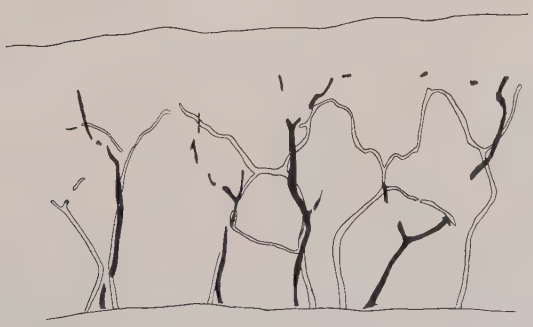

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reconstruction from serial sections proves that this method is unreliable for the study of the development of the lymphatic system, for since it is impossible to reconstruct known vessels the method cannot demonstrate the extent of unknown vessels. This is especially striking when a weak protoplasmic stain is used, for with such a stain many lymphatic capillaries are invisible, and blood capillaries can be but poorly recognized, continuous vessels often appearing in a reconstruction as isolated segments owing to the inability to trace their connections. With a more intense protoplasmic stain, which brings out a differentiation between lymphatic and blood vascular endothelium, it is possible to reconstruct these structures more completely, especially with the oil immersion lens. But still it is impossible to reconstruct with certainty all the lymphatics and blood vessels. Moreover it should be noted that the fitting together of successive sections in a reconstruction is relatively simple here, since all the vessels lie in practically one plane.

In the light of these results let us examine the evidence for the two views under discussion. Lewis and McClure find in attempting to make reconstructions from serial sections, isolated endothelial-lined spaces. It is suggested that these are parts of the blood-vascular system which have become detached and that they may unite to form lymphatics, inasmuch as lymphatics appear later in these same regions. Until more decisive evidence is produced this must remain as merely one of a number of possible explanations of these spaces. Perhaps the most plausible explanation is that their isolation is only apparent, that they are really continuous parts of the blood vascular or of the lymphatic system, and that their connections are missed in the reconstructions, just as was the case in my own reconstruction. Two other explanations are also possible, namely, that they may be portions of blood vessels or of lymphatics which have become detached and left to atrophy during the rapid transformations through which these systems pass in the course of development. Isolated blood vessels undergoing atrophy have been seen in the tail of amphibian larvae by Mayer and I have seen a number of instances in which small portions of lymphatic capillaries become cut off and then degenerate; on both these points I hope to make more definite observations. Until these other possibilities are excluded this view of lymphatic development cannot be accepted.

The evidence for the second view, that the endothelium of the lymphatic vessels is formed from mesenchyme cells, is equally inconclusive. It is based almost entirely on the study of serial sections. Though it is somewhat difficult to discover the precise way in which the conclu-

sion is reached, but according to Huntington and McClure it seems to be about as follows. There are to be seen in sections spaces in the mesenchyme without endothelial lining. These occur most abundantly around collapsed veins as 'extra-intimal spaces,' but they also are seen away from blood vessels. In serial sections these spaces may often be followed through several sections, and in a reconstruction appear as isolated vesicles. Again, there are found in attempting to reconstruct from serial sections, what seem to be isolated endothelial-lined spaces. Subsequently in the same region continuous endothelial-lined vessels are to be found. By interpreting these findings in a convenient way and bridging over gaps the theory is evolved that the endothelial-lined spaces are formed from the spaces without endothelium by a flattening out of the mesenchyme cells, and that the continuous lymphatic system is formed in turn by a coalescence of these isolated endothelial-lined spaces. That this can be considered as nothing more than an hypothesis is shown by a critical examination of the evidence. The isolated spaces without endothelial lining may be interpreted in several ways. The most plausible interpretation is that they are shrinkage spaces which have arisen during the handling of the tissues. That such spaces are possible is shown in fig. 4, where a shrinkage space is to be seen around the collapsed caudal vein, a vein which during life is the healthiest vein in the tail. The spaces away from the blood vessels may also be shrinkage spaces made possible by slight tears of the delicate meshwork of fibrillae of the mesenchyme cells. Miss Sabin[26] has suggested that some of the spaces may be perineural spaces. Again, since the weak protoplasmic stain used brings out the wall of a lymph vessel very poorly, it is possible that some of these spaces may be parts of lymphatic vessels whose wall is not recognizable. It may also be noted that in making reconstructions of the blood and lymph vessels in the tadpole's tail as shown in figs. 6 and 7, many of the 'isolated vessels' seem to communicate directly with the mesenchyme spaces in the sections while no such connection exists in the living tail. This observation is noteworthy because Huntington and McClure lay much stress to such connections when seen in sections of mammalian embryos.

The isolated endothelial-lined spaces are open to the same possibilities of interpretation as those found by Lewis and McClure; a repetition is unnecessary.

[26] F. R. Sabin: Anat. Rec., vol. 2, 1908, p. 51.

Since these numerous possibilities have not been excluded, and since no convincing evidence is presented for the supposed transformations from mesenchyme spaces to lymphatic vessels, it seems that this view must be rejected, or at least that it must await some conclusive proof before it can be accepted.

The evidence for the third view, that the lymphatic endothelium when once formed is specific and that after the appearance of the primary lymph sacs by the transformation of a venous plexus all the rest of the lymphatic endothelium is formed by a centrifugal extension in which all new lymphatic endothelium is derived from preëxisting lymphatic endothelium, is based principally upon the results of two methods of study, namely, the injection method and direct observation of the growing lymphatics in the living larva. In studying the lymphatics in the skin of embryo pigs with the aid of injections, Miss Sabin found that, starting from the region of each of the four primitive sacs, there is a gradually increasing zone of injectible lymphatics which eventually covers the entire body. She was unable to find by injection any remaining isolated lymphatics, and was naturally led to the conclusion that the growth of the system was a centrifugal one taking place by the sprouting of preëxisting endothelium. This result has been confirmed by H. Hoyer and his pupils who studied the development of lymphatics in the skin of bovine embryos by means of the injection method. G. Heuer has found a similar centrifugal extension of injectible lymphatics in the intestine of pig embryos.

The efficacy of the method of injection may be well tested in the tail of the frog larva for it is possible by inserting a fine glass cannula into the thicker portion of the membranous expansion of the tail to fill the lymphatics. The tail may then be examined immediately while the larva is alive and again when it has been fixed in alcohol. These in turn are to be compared with a control drawing of lymphatics before the injection was made. Numerous tests have shown that the injection mass usually fills the entire set of capillaries. There is, however, considerable difference in the extent of the injection, depending upon the amount of pressure under which the mass is injected. Too little pressure fails to fill all the capillaries to their ends. With too great pressure there is produced a mossy appearance around the capillary, as has been pointed out by Hoyer,[27] due evidently to forcing the injection mass through the lymphatic wall. The material thus forced through the

[27] H. Hoyer: Extr. du Bulletin de l'Acad. des Sciences de Craeovie, July, 1905.

wall remains close to the capillary, and still serves to indicate the position of the lymphatic. If the larva is allowed to live for some time after such an injection this extravascular mass may be the only injected material left, owing to the washing out of the material inside the vessels by the flow of lymph. With the proper amount of pressure the lymph capillaries may all be filled solidly with the injection mass and held in position by a rapid fixation. In general it may be stated that when used with care the injection method may be relied upon to demonstrate the full extent of the lymphatic system at any given stage. In comparison with the method of reconstruction from serial sections the injection method is surely superior. With it confusion of blood and lymph vessels is eliminated by the general pattern which is quite characteristic of each system. If this does not suffice, the blood vessels may be filled with an injection mass of different color.

Though the injection method is much more reliable than the study of cross sections to determine the extent of the lymphatic system at any stage, many questions as to the exact way in which growth takes place cannot be determined by it. While the gradually widening area of injectible lymphatics as revealed by this method points strongly toward the centrifugal growth by sprouting, the possibility of some other mode of growth is not entirely excluded. For the study of the finer processes involved in the growth of the peripheral lymphatics the direct observation of the living structures offer decided advantage over all other methods. The fin expansion of the tail of the living frog larva in which blood vessels, lymphatics, mesenchyme cells, wandering cells, and nerves can be seen with great clearness, furnishes an incomparable object for such a study. With the aid of chloretone as an anesthetic and an upright chamber in which the larva remains motionless in its normal position, the same specimen may be watched for many hours daily during a period of several weeks and successive records may be made of the growing structures. Studies carried on by the author, part of which have been published, prove that the lymphatics grow by a process of sprouting in the tail of the frog larva and that new lymphatic endothelium is derived wholly from preëxisting lymphatic endothelium and not from transformed blood vessels nor from transformed mesenchyme cells.

For such a fundamental embryological process as the mode of development of the lymphatic capillary it is highly probable that the course followed in amphibia takes place also in the higher forms, including mammals. Surely so strong is the probability of this being true that it may

be accepted as such unless overwhelming evidence is produced in favor of some other mode of development. As has been pointed out above, no such convincing evidence has been presented by those who have proposed the hypothesis that peripheral lymphatics grow by the addition of transformed blood vessels, nor by the champions of the hypothesis that the lymphatic system develops and expands by the continuous addition of numerous mesenchymal spaces. The latter view rests upon the method of reconstruction which fails utterly because the entire lymphatic system, especially at its growing end, cannot be seen in serial sections and therefore cannot be reconstructed.

REORGANIZATION OF THE DEPARTMENT OF ANATOMY AT CORNELL UNIVERSITY MEDICAL COLLEGE, NEW YORK CITY

The improvement in medical education which has taken place in America during the past twenty-five years is in a large measure due to the absorption of medical schools by universities. As a result of this, the quality of the work in the fundamental scientific branches has been raised to a university standard. The same reformation has not as yet taken place in the clinical branches. The departments teaching the fundamental scientific branches have been reorganized and competent specialists have taken the place of amateur teachers who were often mere exploiters. From time to time we have taken notice of this development in the pages of THE RECORD so far as it relates to the progress of anatomy.

Growth of anatomical science could not take place in departments of anatomy which existed only for the sake of surgery, but instead it took root in the departments of zoology, physiology and pathology where the use of the microscope was understood. Gradually this general development reacted on anatomy and professional anatomists were enlisted in the cause. These naturally demanded as their field of work the whole science of anatomy, and the part-time professor of gross human anatomy began to find himself without a vocation. Anatomy of the living body displaced anatomy of the cadaver. The scope of the work was necessarily extended to include general anatomy and embryology. Progress in this direction seemed to take place very slowly in New York City, but once started it has been carried on with gratifying rapidity. A few years ago Professor Huntington of Columbia University initiated this movement and consummated a transference of histology and embryology to his department. Last year a professional anatomist was called to Bellevue with a view of reorganizing the work there.

Now Cornell University Medical College announces that the separate divisions of anatomy, which have been running more or less automatically, will be united to form a single department to be conducted in the interests of science and of medicine. The election of Professor Stockard to this chair is an event of much importance, for he is a modern,

progressive and scientific anatomist whose investigations give assurance that the work there will be of a high quality. There is every reason to hope that this new department will in the near future take a prominent position in this country.

Professor Stockard received his doctor's degree from Columbia University in 1906, where he did his first work with Professor Dean in comparative anatomy and with Professor Morgan in experimental embryology. Since then he has served as an investigator in the marine laboratories at Cold Spring Harbor, Woods Hole, Dry Tortugas and Naples. Two years ago he was promoted to an assistant professorship at Cornell. During the past five years Dr. Stockard has been unusually productive as his sixteen important contributions, as well as many minor papers on descriptive, comparative and experimental embryological subjects, bear witness. His investigations have shown that activity and rest have no influence over the rate of regenerative growth, and that the process of regenerating tissue has a most exhausting effect upon the animal body. He has also shown that by means of chemicals, defects may be produced which offer favorable material for the analytical study of complex organs and by changing the chemical environment in which eggs develop it is possible to cause them to form a great number of monsters of exactly the same type as those occurring in nature. Thus by properly arranging the chemical treatment he produced from normal eggs with remarkable regularity a specific type of monstrosity, for example, cyclopean monsters, which observation must be regarded as one of the most important in experimental teratology. His work shows acumen in ascertaining the important points of a problem and sifting the value of the evidence. It is clear that it is his belief that scientific anatomy concerns itself with problems rather than with the indiscriminate collection of data for their own sake. Dr. Stockard is an experimental anatomist whose broad foundation insures scientific anatomy at Cornell. He will stimulate a scientifically productive attitude to develop broadly along the several phases of anatomical investigation. Of necessity this will make the department more useful to the practical courses which follow and depend upon it.

A CRITICAL STUDY OF THE EVIDENCE PRESENTED IN SEVERAL RECENT ARTICLES ON THE DEVELOPMENT OF THE LYMPHATIC SYSTEM

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TEN FIGURES

A review of the recent work on the development of the lymphatic system shows that there are marked differences of opinion on fundamental points and a study of these differences will demonstrate that they center around the question of methods. We differ because our methods differ and therefore it is essential to submit the methods to comparative tests and to understand the limits of error of each one. At the present time there are at least ten laboratories engaged in solving the problem of the development of the lymphatic system, the investigators being Hoyer, Mierzewski, Polinski, Jolly, Marcus, F. T. Lewis, Huntington, McClure, Stromsten, Allen, Knower, Clark and myself. From this list it can be seen that the majority of modern investigators are basing their work on the theory that the lymphatics are derived from the veins rather than from tissue spaces, that they are lined by true endothelium rather than by undifferentiated mesenchyme cells, and that they are definite vessels with definite walls as sharply differentiated from tissue spaces as are blood capillaries.

It is unnecessary to recall the various studies which pointed the way toward the theory of the venous origin of the lymphatics, suffice it to say that there have been three important points established by modern workers: first, that the primary lymphatics are centrally placed lymph sacs, second, that the growth of the

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SEPTEMBER, 1911

lymphatic capillaries is from center to periphery, and third, the exact method of the growth of the lymphatic capillary by means of sprouts of endothelium.

In regard to the lymph hearts I shall refer to the subject only in the mammalian form. The first mention of the mammalian lymph sacs of which I am aware was made by Saxer. He was considering the question of the histogenesis of wandering cells in developing lymph glands and mentions that he found symmetrical sacs in the neck of a sheep embryo 25 mm. long. The next reference to these lymph hearts is to be found in my own work, the significance of which can be readily brought out through a criticism by Huntington and McClure ('10, p. 183) in which they say in connection with the idea that the lymph sacs are the first lymphatics and come from the veins that a similar and equally valid inference might have been drawn by observing the conditions which prevail in the adult. This criticism is just only if you omit the entire point of my paper. When I began my work, it was the accepted theory that lymphatics arose from the tissue spaces and then grew toward the veins. The theory involved the conception that the earliest lymphatics were to be found in the periphery and the later ones in the center of the embryo. Von Ebner, in the last, that is the sixth, edition of Koelliker's Gewebelehre (Leipzig, '02, p. 681) calls attention to the fact that Ranvier injected the cutaneous lymphatics in foetal pigs 90 mm. long, that he noted the distal growth of lymphatic capillaries within the plexus by sprouts which were at first solid and then became hollowed out and that he concluded from this that the growth was from center to periphery and hence that the lymphatics came from the veins. To this conclusion Von Ebner says that were it true, it would be an important, fundamental, distinguishing point between lymphatics and tissue spaces, for tissue spaces develop everywhere *in loco*. He adds that Ranvier's theory is in no way certain and stands, on the contrary, in contradiction to other known facts, but he quotes it because it gives the clearest expression of the entire difference between tissue spaces and true lymphatics. Thus it is clear that Von Ebner, though not accepting Ranvier's theory, understood its significance.

In studying the development of the lymphatics in the skin of embryo and foetal pigs, ('01–'02 and '04) I found that the exact reverse of the accepted theory was true, namely, that the first lymphatics are in the center of the body and not in the subcutaneous tissue. It was easy to get the injections that Ranvier had, and to note, as he did, that a coarse-meshed plexus grew into a fine one by sprouts of endothelium which bridge the gaps. But I found that the foetus 90 mm. long might almost be considered in the adult condition for in it the lymphatics had spread all over the skin. By following the lymphatics back stage by stage I found that they gradually receded from the periphery. The skin lymphatics drain into the sacs and in order to find them in younger and younger embryos one must inject nearer and nearer the sac. At last a stage is reached when there are no lymphatics in the skin, but the sacs still remain close against the vein. Thus I traced the lymphatics back to the vein. The facts are correct and have been verified, the reasoning was correct and has been justified. The hypothesis which I advanced that the sac started as a bud or sprout from the vein was of value until Dr. Lewis traced the process back a step farther and showed how the sacs 'budded' or developed directly from the veins.

F. T. Lewis ('06) with a few, but carefully studied specimens, established the method of formation of the lymph sacs as it is accepted by everyone who has studied the subject since, except Stromsten. Lewis figured the primary blood capillary plexus draining into the internal jugular vein better than anyone else has done it since though not so completely as it could be done by the injection method; he found that there is a stage when the sac is separated from the main vein, the permanent opening being secondary; he showed the relation of the sac in position to the external and internal jugular and the primitive ulnar veins and to the cervical nerves; he brought out the fact that in reconstructions of lymphatic capillaries there are to be found isolated endothelial-lined anlages in growing areas. The latter observation gave him the suggestion that lymphatics may grow by the continual addition of vessels cut off from the blood vessels. This has been one of the most interesting contributions to the study of the

lymphatic system and to submit a test of the meaning of these isolated spaces is the object of this paper.

These facts have all been confirmed. In regard to the separation of the sacs from the veins and their subsequent rejoining, one must recognize that it is a difficult point to accept especially as it rests on the negative evidence of not finding the connections in sections. Moreover, if these connections were guarded by valves the openings would be increasingly difficult to find. The method of injection gives a certain amount of evidence on the point. (1) At a certain stage all of the capillary plexus which drains into the jugular vein can be filled by an arterial or a venous injection. (2) Later a blood vascular injection, complete, elsewhere, does not fill certain dilated capillaries which are filled with blood, or perhaps enters this capillary plexus on one side and not on the other. At this stage the sac has never been directly injected to see if it connects with the vein or not. (3) Still later a vascular injection never enters the sacs which are now empty of blood, but an injection into the sac either directly or through the skin lymphatics always runs over into the veins. At this stage a valve can be seen in sections. To explain the second stage, in which an injection does not run from the vein to the sac, and in which the valve is not found in sections, we have the provisional interpretation, namely, that the sacs are temporarily separated from the veins.

In regard to the jugular lymph sacs, Huntington and McClure have studied the process in another animal, namely, the cat. Though they began with the theory that the jugular lymph sacs were 'extra-intimal' spaces, they abandoned this idea through their own work, and came to accept the conclusions of Dr. Lewis. They have, however, added the theory that the jugular sacs are formed in part by a process which they call 'fenestration.' This idea of fenestration is clearly stated and illustrated in their second paper ('08, p. 8) as a longitudinal splitting of a vein to form two parallel channels. Thus in describing their figures they say, "The stippled area indicated on the figures (figs. 7 to 11 inclusive) represents the portion of the venous system which is subsequently split off from the main venous channels and which becomes

transformed . . . . into the definite lymph sacs." This seems to indicate the process of the splitting of a vein to form capillaries, but the following quotation of the meaning of the term as given in a subsequent publication ('10, p. 203) is so veiled in obscurity that one is perhaps not justified in assuming that they still use the term in the same sense as originally defined.

> By this designation, that is 'fenestration,' we do not mean to define a method of histogenetic formation of the early blood vessels, but to accentuate, by the use of a brief and serviceable term, the fact that in certain stages in the development of the venous system . . . . . the early embryonic pathways exhibit a typical and characteristic picture, best defined by the term fenestration. The main lines of venous drainage have become fairly defined out of the antecedent primary capillary network from which they arise. In the further growth of the embryonic tissues secondary plexiform capillaries surround the main vessel and become connected with the same. By condensation of this plexus and enlargement of the interrecticular spaces the principal embryonic veins appear in this developmental phase as channels perforated by larger spaces 'fenestrae' within the general confines of the general trunk. In a subsequent stage confluence of these fenestrae results in a more or less complete separation of the primary vein into two parallel secondary channels, which appears to be a uniform principle in the development of parallel venous trunks . . . . The term fenestration means, therefore, in the sense in which it is employed in *this* paper, one of the last stages in the definite crystalization of the venous system out of an indefinite antecedent plexiform condition . . . . It does not mean the formation of lacunae or spaces in veins already fully established . . . . Such fenestral separation may result in the establishment of a secondary vein paralleling the course of the main channel, as in the case of the postcardinal and primitive ulnar veins, or, specifically, in the development of the jugular lymph sacs the areas involved separate by 'fenestration' from the vein proper to constitute the anlages of that portion of the lymphatic system which is derived, as a veno-lymphatic plexus or sac or modified mammalian lymph heart, directly from the veins.

It will be readily seen that it is difficult to determine exactly what is meant by the term since they disclaim the idea that this process corresponds to a "method of histogenetic formation of the blood vessels" and yet they still regard it as one of the two processes by which the lymph sacs form, the second being the transformation of a capillary plexus as described by Lewis. The term, however, will serve to emphasize the fact that no proof has

been given that the lymph sacs form in any other manner than that shown by Dr. Lewis, namely, as a transformation of certain blood capillaries. This is wholly in accord with the modern ideas on the growth of blood vessels, that in the main the place of growth is in the capillary bed. It is out of capillaries that both arteries and veins are formed. The breaking down of veins into capillaries which is perhaps involved in the term 'sinusoid' is however known to occur in the case of the omphalo-mesenteric vein as it passes through the liver. If it is this process that Huntington and McClure really mean, that the sac comes in part from the vein, their evidence for it is given mainly in composite diagrams rather than in figures that represent actual models, and the idea is at best a poorly supported hypothesis. The point which has really been proved is that the jugular sacs are transformed blood capillaries. The elaborate study of the jugular lymph sacs by Huntington and McClure does not equal to my mind the previous paper on the same subject by Lewis, who showed a grasp of the value of a few critical stages chosen with judgment and clearly presented so as to emphasize the fundamental points.

Stromsten, a former pupil of Dr. McClure, differs from both Huntington and McClure in thinking that the lymph hearts are in part of mesenchymal origin. He finds that the formation of the posterior lymph hearts is "initiated by the vacuolation of the post-iliac mesenchymal tissue" ('10, p. 86), and that into this loose connective tissue capillaries from the postcardinal veins grow. In describing the same process in a subsquent paper ('11a, p. 175) he says in connection with the development of branches of the postcardinal veins:

> The formation of this pair of veins produces profound changes in the post-iliac spongy area. Great spaces or channels appear. These spaces seem to be enormously dilated capillaries which intercommunicate with each other, and connect with the accompanying veins at one or two points. They contain red blood cells, and are indistinguishable from veins except by position. They correspond to the veno-lymphatics of birds and mammals.

Again in regard to these 'veno-lymphatics,' he says, "It appears as though these spaces had captured, as it were, certain capillaries and converted them into the anlagen of the lymph hearts" ('10, p. 86). However, though he uses the term 'veno-lymphatic,' he makes it quite plain that he does not use it in the same sense as it has been used in mammalian forms where it means lymphatics derived from the veins. On the contrary he thinks that the venous endothelium is only in part the source of the lining of the veno-lymphatics, for he says, "Veno-lymphatic channels are formed by the confluence of the mesenchymal spaces with each other and with the invading capillaries" ('10, p. 86). In a printed abstract of a paper read before the Iowa Academy of Science, (April 29, '11b) he says, "The lymphatic endothelium arises entirely independently of the venous endothelium by the flattening of the original mesenchyme cells." Thus it is clear that Stromsten regards the lymph sacs of mixed origin, partly from vascular endothelium and partly from mesenchyme cells, while he regards the lymphatic vessels as of mesenchymal origin. Unfortunately the figures given by Stromsten are either photographs or are too diagrammatic to help one in understanding his material.

In regard to the other sacs I may pass over the paired posterior and unpaired retroperitoneal sacs which have been fully discussed in my other papers ('09 and '11) but will discuss briefly the cisterna chyli and thoracic duct.

The cisterna chyli has been found in the pig and in man. It covers an extensive area in the pig, arising from the tributaries of the azygos veins, dorsal to the aorta at a level corresponding to the position of the adrenal anlages. In two embryo pigs of the same litter measuring 23 mm. there is a median anastomosis of the azygos veins in this area, which in the one specimen had been injected through the veins, while in the other uninjected specimen it is full of blood while the surrounding veins are empty. At a later stage, namely at 25 mm., these same vessels form a definite, empty lymphatic sac. It is not possible to set limits to the transformation of veins into lymphatics making the cisterna chyli and thoracic duct, for by comparing the

two specimens measuring 23 mm. it can be seen that vessels which are clearly branches of the azygos veins in the one specimen do not seem to connect with the vein in the other. The thoracic duct develops in part as a down growth of the jugular sac and in part, especially its dilated portion or cisterna chyli, as a direct transformation of the branches of the azygos veins. These observations must be considered in the light of the tests on limitations of methods to be brought out later. I maintain and can prove by injections that connections can be demonstrated between apparently isolated lymphatics which can not be found in sections of uninjected specimens. Therefore in a new territory one can not be certain of the extent of the lymphatics without injections. There are two processes involved in the origin and development of lymphatics, the first a transformation of blood capillaries from vessels which once carried blood to those which carry lymph, and secondly the growth of these primary anlages by the same method as blood vessels grow. The essential elements in the change are (1) the separation of certain vessels out of the line of circulation of artery, capillary, vein, and (2) the formation of valves at their point of communication with the veins. The first lymphatics are the lymph sacs which with the thoracic duct make a primary system. From this primary system there develops the secondary or peripheral system. The essential point which becomes clear from this theory of the origin of the lymphatic system is that lymphatics are lined by an endothelium which is derived from the veins. This is well brought out by Professor Minot in the following quotation: "Mit anderen Worten, es ist wahrscheinlich, dass die Endothelium der Blutgefässe (und der Lymphgefässe) und die Blutzellen in jedem Stadium sämtlich direkte Abkümmlinge des primitiven Angioblasts sind" ('11, p. 484).

Having thus reviewed the evidence for the theory that there is a primary system consisting of sacs which are transformed blood capillaries, I will pass to the subject of the secondary or peripheral lymphatic system. Here must be discussed many of the most interesting questions which center around the lymphatic system, how the lymphatics invade the body, how the capillaries grow,

the relation of their walls to the surrounding mesenchyme cells, the relation of the great tissue space or lymph carrying system to lymphatics, the problem of the serous cavities, and finally the time honored question of open and closed lymphatics.

The first point which I regard as proved and which forms the foundation for understanding the morphology of the lymphatic system as a whole, is that the primary lymphatic vessels arise directly from the veins. The second fundamental point which has been proved is that the peripheral spreading of lymphatics from the sacs is by means of the growth of the endothelium which lines them. But it is here that there is so great a difference of opinion that the point can not be called generally accepted. This question involves the nature of the growing tip of the lymphatic capillary—the capital question of the lymphatic system—involving as it does the question of open and closed lymphatics. This is the question which has occupied the attention of many great investigators for two hundred years. Dr. Mall has suggested that a series of diagrams will perhaps express the various views which have been held and are held in connection with the relations of the vascular system and the tissue spaces. Such diagrams may be helpful in clarifying our views though it must be remembered that in thus graphically interpreting the views of others I may make them more definite than they would be willing to admit. In the diagrams the veins are longitudinally striated, the true lymphatics are dotted, the hypothetical lymphatics are cross-hatched and the connective tissue is in solid black lines. The first figure will serve to call to mind the 'vasa serosa' of Boerhave, Haller, Bichat and others which are hypothetical channels thought to connect arteries, veins and lymphatics at their tips. With the discovery of cells, the 'vasa serosa' gave place to the theory of Schwann and Virchow, namely, that veins and lymphatics were connected by hollow connective tissue cells (fig. 2). The nuclei in the figure which are not present in the first make this point plain. Fig. 3 gives Von Recklinglausen's view of the nature of the tip of the lymphatic capillaries which he believed communicated directly with the connective tissue spaces. The next diagram (fig. 4) together with fig. 9*a*, and *b* represents the

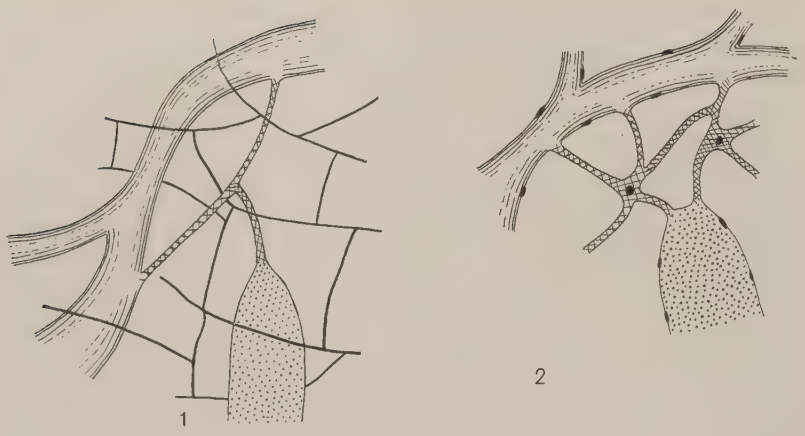

Fig. 1 Diagram to express the 'vasa serosa' of Boerhave, Haller, and Bichat and others. The vein is longitudinally striated, the lymphatic vessel is dotted, the 'vasa serosa' connecting the two are cross hatched. The connective tissue is represented by lines.

Fig. 2 Diagram to express the view of Schwann and Virchow that the blood vessels and lymphatics are connected at their tips by hollow cells. The veins are striated, the lymphatics dotted and the hypothetical lymphatics cross hatched. The nuclei represent the fact that cells had been discovered.

view which I believe can be proved. Starting with Ranvier, who noted that the growth of the lymphatic capillary plexus was by endothelium, i.e., from center to periphery, and followed by my work which traced the lymphatics of the skin back to the vein, there arose the conception expressed in fig. 4, namely, that the endothelium of the lymphatic capillary is derived from the endothelium of the blood capillaries at certain places in the center of the embryo close to the vein. This is expressed in the term 'venous origin of the lymphatics.' The further development of the subject as presented by Lewis (fig. 5) showed that in serial sections of uninjected specimens there are isolated spaces containing no cells and clearly lined by endothelium. These spaces can not be seen to connect either with a vein or with nearby lymphatics but they occur in regions in which lymphatics are developing. The theory relating to these anlages is really a revival of Sigmund Mayer's theory who approached the subject

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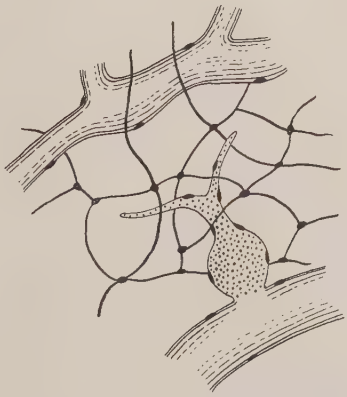

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Fig. 3 Diagram to show Von Recklinghausen's idea of the relation of lymphatics to tissue spaces. All of the tissue spaces are cross hatched to represent hypothetical lymphatics.

Fig. 4 Diagram to show the view that the lymphatics are derived from the veins according to Ranvier and myself.

from an entirely different standpoint ('85). He studied the living lymphatics in the tadpole's tail and was impressed as Langer had been before him with the idea that lymphatics probably grow in the same manner as blood vessels. He was considering the question as to whether the lymphatics connect with the blood vessels at their tips and concludes that if so it is only by solid threads making a pseudo-connection. Then he goes on to say that possibly a certain number of blood vessels may be shunted out of this system and then persist as structures which are more or less independent of the blood vessels. This process, he adds, may indicate a genetic relation between the lymphatics and the blood vessels. It is now generally believed that this process actually takes place in the formation of the lymph hearts. The numerous isolated endothelial-lined spaces which occur in the neighborhood of growing lymphatics I shall call Mayer-Lewis anlages. Mayer and Lewis have formed an alternative and entirely possible theory different from mine, namely, that the primary lymphatic system once formed grows by means of frequent additions from the blood capillaries. It has therefore been essen-

tial to study these isolated anlages by submitting our various methods of study to comparative tests. The recognition of the necessity for such study, and the beginning of it, will be found in the paper which I read at the meeting of the American Association of Anatomists in Chicago ('08, p. 46). Both Dr. Clark and I have submitted our material to such tests. At the meeting of the Association in Ithaca, December, 1910, I demonstrated a foetal pig 27 mm. long in which the right jugular lymph sac

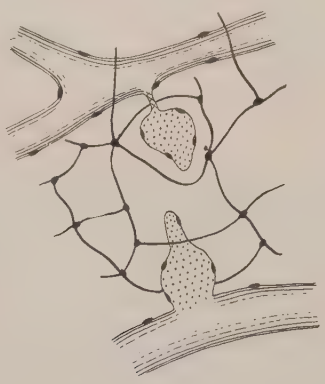


Fig. 5 Diagram to represent the Mayer-Lewis anlages that is, that besides the sacs which are derived from the veins, the lymphatic vessels grow by numerous direct anlages from the veins. This view was also temporarily held by McClure.

and the peripheral vessels leading to it were injected. Fig. 6 gives a picture of the specimen. Since then the embryo has been imbedded in paraffin, cut into serial sections 20 μ thick, and stained with haematoxylin and Van Gieson stain. A given area of the head, chosen because the lymphatics were nearly at one level, has been reconstructed on both sides, the one injected and the other uninjected. The reconstructions were then made on millimeter paper using the original mid-dorsal line of the embryo from the drawing of fig. 6 as the guide. The injection covered the curved surface of the head but in making the reconstructions the vessels have been projected to the median plain of the embryo. For the sake of ease in the work the projection was made on similar oblique lines. The drawings for

the reconstruction were made at a magnification of 50 diameters with a Zeiss projection apparatus but it was found necessary to submit every section to further study with a Zeiss 4 mm. lens, magnification 375; adding the tiny sprouts which are not noted at 50 diameters to the drawings by means of the camera lucida in order to reconstruct the injected plexus. A few of the sections were studied with the oil immersion lens. In fig. 7 is shown the reconstruction of the injected plexus in which the vessels are shown in solid black and the extravasations in dotted areas. The injection was almost complete, there being only one endothelial-lined vessel not containing ink but it was adjacent to an extravasated area. A few of the vessels connected with the main plexus through extravasations so dense that the endothelial wall could not be traced. The fundamental point is well brought out that an elaborate plexus which has been injected can be reconstructed almost completely, leaving very few isolated islands. On the other hand, fig. 8 shows a reconstruction of the same area on the uninjected side, the drawing of every section having been tested in exactly the same way with the 4 mm. lens and all endothelial sprouts of which I could be sure added before the reconstruction was made. It must be emphasized that the drawings include only endothelial-lined spaces and that these endothelial-lined spaces corresponded with vessels on the opposite side which are known to be lymphatics through their connection with the lymph heart. The figure shows many of the isolated lymphatics, or Mayer-Lewis anlages. These are true lymphatics. This test demonstrates the point which I brought out in 1908, pp. 53-54, that one can inject more of the true lymphatic plexus than one can reconstruct and that an uninjected lymphatic capillary plexus can not be fully reconstructed but rather breaks into the Mayer-Lewis anlages. This point is, I think, well recognized in the case of blood capillaries which are perhaps even harder to reconstruct than lymphatics because they are smaller and collapse more readily, as has been observed by many investigators in the living tadpole's tail. I am well aware that the lymphatic plexus used in this test though simple for the skin, is not as simple as the capillary plexuses reconstructed by Lewis

in earlier stages. As soon as lymphatic injections can be obtained in earlier stages they should be submitted to the same test.

What is here brought out is fully confirmed by Dr. Clark's study ('11) of the tadpole's tail which gives every possible advantage, first and above all, the chance of seeing the entire lymphatic capillary down to the tiniest thread of protoplasm in the living

Fig. 6 View of an embryo pig 27 mm. long in which the vessels over the scapula and behind the ear have been injected. (× 3). The track of the needle is in line with the shoulder; the jugular lymph sac, just below the ear, is dotted. The injection is almost complete. The line across the injection is to indicate the small area which has been reconstructed.

specimen, secondly, a plexus which is extremely simple and in a single plane, and thirdly, the chance to reconstruct exactly the same plexus which he had seen in the living animal. This is more conclusive than my test which involved comparing the injected plexus with the reconstruction of the one on the opposite side of the embryo. Clark has made various studies of the same specimen, given first, in a drawing of the lymphatics in the total

specimen, secondly, in a reconstruction with a 4 mm. Zeiss objective, and thirdly, with a 2 mm. oil immersion. His figures show that under most favorable conditions in the study of a known area and with intensely stained sections, neither a blood capillary

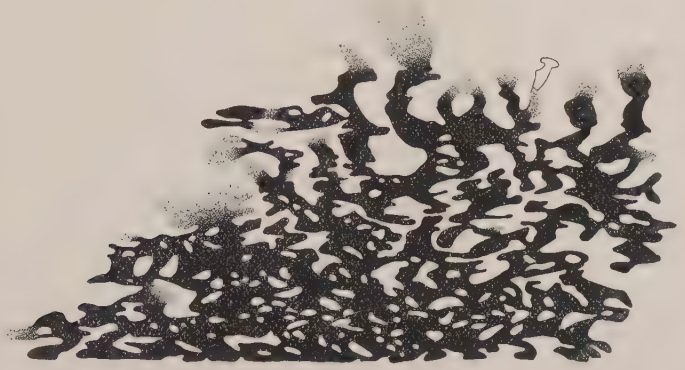


Fig. 7 Reconstruction of the area anterior to the line on fig. 6. (× 25) The dotted areas are extravasations, the solid black represents injected vessels and the one outlined space is an uninjected endothelial lined lymphatic.

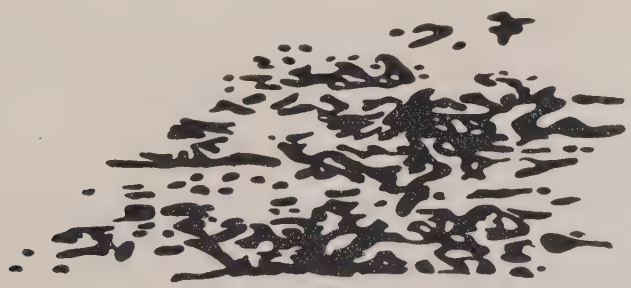


Fig. 8 Reconstruction of the area corresponding to fig. 7 on the opposite side of the head. (× 25) All of the vessels shown are definitely lined by endothelium.

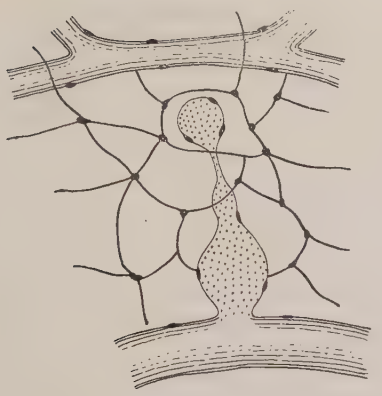
nor a lymphatic capillary plexus can be reconstructed completely. The growing tip which is connected with the main lymphatics in the living specimen, nearly always appears as an island in a reconstruction.

The question of the degeneration of capillaries should also be considered in connection with the Mayer-Lewis anlages. It was

first observed by Ranvier ('95–'96) that in the mesentery of the pig there were isolated endothelial-lined spaces separate from the lymphatic plexus which he interpreted as degenerating lymphatics. Dr. Clark has observed such a separation of islands from the rest of the plexus and their subsequent disappearance but it is not a common occurrence. Vessels usually retract instead of becoming cut off in a growing zone but their separation does sometimes occur. From these studies of Dr. Clark and myself, it is a legitimate conclusion, that the Mayer-Lewis anlages, which are the isolated endothelial-lined islands in sections of vascular and lymphatic areas, are all true vessels, either blood vessels or lymphatics whose endothelium is derived from previous endothelium. With the exception of a few degenerating vessels, the Mayer-Lewis anlages connect in the living specimen, and can be injected. They stand in the strongest contrast to the mesenchyme spaces on account of their endothelial lining. Thus the Mayer-Lewis anlages we have been studying are lymphatics.

The results of the tests of method made by Dr. Clark and myself are given in two diagrams (fig. 9*a* and *b*). The first one shows that in the living as well as in the injected specimen all of the lymphatics can be seen as a continuous plexus draining into the vein, while in the uninjected fixed specimens the lymphatic plexus breaks up into Mayer-Lewis anlages at its growing periphery.

Huntington and McClure have criticized the injection method by saying that it fails to demonstrate all the lymphatics. They say, "Injection will, if successful, only demonstrate channels or spaces actually continuous with each other at the time of the injection, but will completely fail in revealing vascular spaces as yet independent of those injected, although subsequently a connection between the two may be established" ('10, p. 180). Stromsten has made more specific objections to the injection method. "The injection method used alone is unreliable, because (a) only that portion of the lymphatic system which is in direct connection with the point of injection (lymph sacs) is shown, while the unconnected spaces are not indicated; (b) extravasations and accidental venous injections vitiate the results."('11b)



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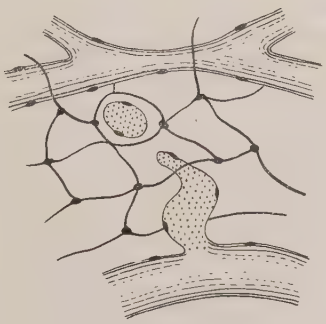

9b

Fig. 9*a* and *b* Diagram to show the effect of fixing and sectioning lymphatic capillaries as proved by Clark; *a*, the relation of the lymphatic capillaries to the veins and the tissue spaces which can be seen in the living animal; *b*, the same lymphatic vessel as it appears after fixation and sectioning. That is to say, the Mayer-Lewis anlages are produced by hardening, dehydrating and cutting.

That the injection method used alone is unreliable is barely worth an answer, for no competent investigator uses it alone but always in comparison with uninjected specimens. The value of the injection method is well known to every teacher of histology. For example, compare the conception of the capillary plexus around the air sacs of the lung, or in the glomeruli of the kidney or the islands of Langerhans in the pancreas as shown by good injections, with that which can be obtained from studying uninjected sections. Even more valuable has been the injection method as applied to the study of embryonic tissue. Through the injection method it has been brought out that the growing blood vessels develop into perfectly definite and constant zones, new vessels have been found where none were known to exist, and plexuses have been shown to be exceedingly rich and abundant where but few and scanty vessels were known. Thus the injection method for the study of blood vessels and of lymphatics has marked a great advance from the study of sections alone. Doubtless the newer experimental methods will carry us farther than the injection method, especially all the advances that are being made in the study of growth in the living specimens. Here

it is most interesting to note that a good illustration of the limitations in faithfully interpreting the appearances of well fixed specimens is to be found in the observations of Felix, who describes blood vessels in an early human embryo opening freely into the coelom ('10, p. 606). However, the very best test of the injection method which has ever been made is that of Clark, who after having observed the extent of the lymphatic system in the living tadpole's tail, injected the lymphatics in the same specimen and found that the entire plexus could be injected. In studying a growing area which can not be seen in the living form, it is yet possible to find the limits of growth of the lymphatics by means of injection provided there is abundant material. For when at a given stage, an injection repeatedly stops at a given zone and when watched under the microscope this zone has long delicate sprouts or rounded bulbous ends which always rupture under increased pressure, it is fair to conclude that the lymphatics have not progressed farther. Thus the experiments on the pig embryos by myself and especially those on the tadpole's tail by Dr. Clark demonstrate fully that by means of the injection method as well as the direct observation of the living specimen, all of the true lymphatic system can be seen, while by the reconstruction method both the blood and lymph capillaries often appear as islands. Spaces which are truly lymphatic but which appear not connected in sections can be injected. Spaces which in reality do not connect with the lymphatics and are not lymphatics are filled by injection only by rupturing the wall of the true lymphatic. Since mesenchyme spaces have never been seen to join a lymphatic in the living form, the mere assumption that they join is entirely unwarranted. The last objection that extravasations and accidental venous injections vitiate the results is not correct. The venous injections are essential to understanding the problems and the extravasations are easily recognized.

In regard to the crucial point, namely, how the lymphatic tip grows, it is necessary to keep clearly in mind the kind of proof which has been submitted. The method which gave the suggestion of the centrifugal growth of the lymphatic tip was the method of injection which demonstrated the sprouts of endothelium.

These were brought out by Ranvier, McCallum, Bartels and myself. That the idea of the centrifugal growth is only an inference from these observations, not an absolute proof, is to be seen by the fact that Bartels though confirming the observation can not accept the inference on account of the difficulty in imagining a growth against the direction of the pressure of the fluid contained ('09, pp. 46–47). The proof that the lymphatic capillary grows by the proliferation of its own wall was given by Clark ('09) who watched the growth of the capillaries in the living tadpole's tail and made accurate records of the same capillary over periods of weeks. The living capillary is entirely distinct from the surrounding mesenchyme, receives no additions of mesenchyme cells nor isolated anlages, but progresses by the division of the nuclei and the increase of the protoplasm of its endothelial wall. The endothelial wall is a tube of hyaline protoplasm, with granular areas around the nuclei and clearly in the form of a syncitium in growing areas.

It is now necessary to consider the question of tissue spaces, for their physiological significance is such that they deserve more careful study from the anatomical side. The theory which separates off the two great systems of vessels, blood vessels and lymphatics on the one side from the tissue spaces on the other, has its meaning in the idea that the endothelial membrane separates different fluids, blood plasma in the capillaries or lymph in the lymphatics from the tissue juice of the tissue spaces. The terms tissue space (Gewebs-Lücken) and tissue juice (Gewebssafte) were introduced by Waldeyer ('74) in his masterly discussion of the structure of the cornea. He identified tissue spaces with the 'Saftcanälchen' and 'Saftlücken' of von Recklinghausen and showed how, by the use of a variety of methods, silver and gold impregnations, injections under low and high pressure, to demonstrate that they are true structures, not artefacts. He recognized that they contained a serous fluid, tissue juice, which circulated without the aid of vessels.

But the real significance of tissue spaces as an important system in the physiological sense was brought out by Melzer and Adler in 1896:

The tissues of the body are permeated by a system of interstitial spaces which contain the tissue fluid. This system is, by virtue of its structure, its function, and its contents, an independent apparatus by itself, and not an integral part of either of the two systems of vessels, and the fluid within this system is likewise in many important respects different from the fluid of the blood vessels as well as from that of the lymphatics ('96, p. 518).

These conclusions Melzer has further tested by experimental studies of the transmission of fluids through the tissue space system, which he terms the 'peripheral mechanism of distribution,' by means of injections of drugs into cardiectomized frogs. These experiments cause him to exphasize again the difference between the lymphatic system, a series of endothelial-lined tubes, drainage canals, and the tissue space system ('11). The fact of the ready clotting of blood plasma or lymph when mixed with tissue juice also indicates the physiological significance of the endothelial membrane.

In the stages of the embryo which mark the beginning of the lymphatic system, all of the connective tissue is in the form of a syncitium of mesenchyme cells. Yet this syncitium varies greatly in different parts of the body. There are certain areas which are dense and compact, hence containing relatively little tissue juice and others which are loose and open containing much of the fluid. The areas which have the open, loose mesenchyme are definite and constant; they are undoubtedly true structures with an important function. The most conspicuous of these is the zone around the central nervous system, the anlage of the pia arachnoid. This zone has a definite form and development, injections of it give always the same pattern in a given stage but no injections of it ever run into lymphatic vessels. A second zone of such spaces surrounds the peripheral nerves and may be called perineural spaces. These are occasionally injected from the pia arachnoid. A third zone is always to be found in connection with the formation of the parietal pleura and is shown ventrolateral to the vertebrae in figs. 418, 419 and 420 in Dr. Mall's chapter on the coelom and diaphragm ('10), in human embryos from 14 to 19 mm. long. In the foetal pigs from 40-60 mm. there is a conspicuous system of such spaces in the subcutaneous

tissue along the mid-dorsal line. They are so marked as to give the area a translucent appearance in the fresh state, an appearance which becomes markedly increased on slight maceration. Early in my work my attention was called to these spaces and I made many injections of them. If any granular substance is injected into such spaces, the appearances are like extravasations, that is to say instead of definite vessels the irregular protoplasmic network becomes covered with granules while the interstitial spaces are empty. In such loose tissue definite endothelial-lined capillaries both lymphatic and blood vascular are easily seen. Having carefully studied such spaces and eliminated them from the true lymphatic vessels by the fact that they never respond to injections like lymphatic vessels, I can not accept them as lymphatics when they occur along the veins. Sections of embryos show such spaces to be conspicuous in the root of the mesentery, and in certain places along the aorta. Whether they characterize the zones around the degenerating veins or not, can be determined only by more careful studies of the vascular system. As we learn more of the processes of development we shall doubtless emphazise these areas more. It can not be said that such loose areas are always the forerunners of lymphatic vessels, since into certain of these zones, as for example the pia arachnoid, we have no evidence that lymphatics ever invade.

It is now necessary to analyze the theories of Huntington and McClure and their evidence. Throughout Dr. Huntington's work there has run a theory which was stated in his first paper, namely, that there is a relation between the formation of lymphatics and the degeneration of veins. This theory is first stated in connection with the jugular lymph sacs as follows:

> The development of the main lymphatic vessels of the cat occurs in close association with the formation of the early venous channels . . . . The first indications of the lymphatics appear in the region of the precardinal veins. As a result of shrinkage and condensation of the primitive redundant precardinal vein-channels, oval or spindle-shaped spaces appear along the course of the veins. These spaces are situated without the intima of the veins in the peri-intimal adventitious tissue, and are not to be confounded with the mesenchymal spaces of Sala since they develop in territory formerly occupied by the veins themselves ('06–08, p. 38).

These observations were withdrawn as far as they relate to the jugular lymph sacs where Huntington and McClure describe three processes entering into the formation of the sac: (1) the fenestration of the jugular vein, (2) the blood capillary plexus of Lewis, and (3) the Mayer-Lewis anlages. They figure the Mayer-Lewis anlages and refer to them, as for example, "Several detached vascular islands are present" ('10, p. 242) and

> Numerous independent lymphatic structures are found along the course of the large veins. Among these may be mentioned a large complex lymphatic sac which envelops the subclavian vein, and which does not yet join the jugular sac, as far as we can determine. An elongated and fenestrated lymphatic vessel, not yet joined to the subclavian approach, lies ventral to the precava . . . . None of these lymphatic structures communicate with the veins ('10, pp. 305 and 306).

At this point McClure, working independently, changed to the Lewis theory of the formation of peripheral lymphatics by multiple venous anlages in a study of the thoracic duct. In this paper he figures veins ('08, p. 537, Anlage thor. duct, figs. 3 and 5) as the anlage of thoracic duct which I believe never have anything to do with the duct because I have injected specimens both of the blood vascular and the lymphatic systems in which I can show these veins and the thoracic duct in the same section. McClure has retracted the theory presented in this paper and has now returned to the Huntington theory of 'extra-intimal' lymphatics. This theory is presented in three papers by Huntington appearing in '10 and in one by McClure ('10), but it is not used consistently in relation to the formation of the peripheral lymphatics as can be seen in the following quotations:

> The entire extensive system of the lymphatic vessels of the adult, including the thoracic and right lymphatic ducts and their tributaries is formed by the confluence of numerous perivenous and extra-intimal intercellular mesodermal spaces, in the sense previously defined. These primary anlages of the future systemic lymphatic vessels are, from their inception, lined by a lymphatic vascular endothelium, which is not derived from the haemal vascular endothelium, but which develops independently of the same (Huntington, '10, b, p. 400).

The systemic lymphatic vessels of the mammal develop independently of the veins, by the confluence of numerous intercellular perovenous mesenchymal spaces (ibid., p. 402).

The initial development of lymphatic spaces is, however, by no means confined to the immediate environs of a degenerating vein. The same field which demonstrates the histogenetic processes above described in the development of the extra-intimal lymphatic spaces surrounding a decadent vein will, at the same time, show numerous equivalent lymphatic spaces developing independently of antecedent veins as enlarging intercellular mesenchymal clefts (ibid., p. 413).

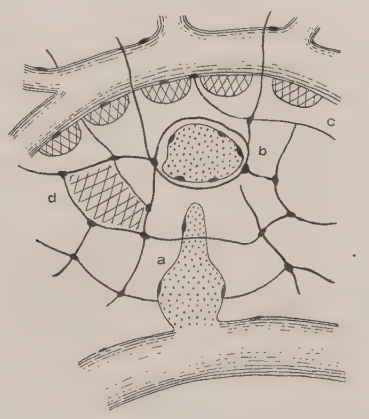

Fig. 10 Diagram to show the various structures which Huntington and McClure have described as lymphatics, *a*, the true lymphatics; *b*, the Mayer-Lewis anlages, also true lymphatics; *c*, extra-intimal hypothetical lymphatics, and *d*, certain of the tissue spaces.

Thus the theory has now enlarged to include the spaces of Sala which were originally excluded as quoted on page 437.

In the same article Huntington explains that by extra-intimal he does not mean that the vascular endothelium enters into the finished lymphatic, but that by shrinkage of the vein there is formed a space between the vein and the mesenchyme. Eventually the vein disappears and the mesenchymal space is left. Thus I think it is clear that fig. 10 represents the various structures which Huntington and McClure have demonstrated as lymphatics, first, the sac of blood vascular origin and the Mayer-Lewis anlages, secondly, for peripheral lymphatics, the temporary extra-

intimal clefts and certain of the mesenchymal spaces but not others.

If we examine the evidence for the extra-intimal theory it is found to rest on the appearance of such spaces in sections. There is no question in regard to the observation; Clark finds extra-intimal spaces in preserved material which were not present in the living form and this is I think most conclusive evidence that they are artefacts. Secondly, the poorer the preservation of the tissue the greater the number of such extra-intimal spaces. In the figures of the spaces in the article just quoted they are all in the center of the embryo where the fixing fluid penetrates last. Therefore, before they can be considered seriously, they must be first tested in the same stage with all the best fixatives to see if they do not vary according to the method used. The next point against them is that lymphatics may grow out ahead of the blood vessels into territories where no veins have ever been. This has been observed by Clark in the living tadpole's tail. Dr. Huntington has met this objection by a partial retraction of the theory, saying that lymphatics may form in part from the general mesenchyme spaces.

This is the old theory of the development of the lymphatic system. As I have already said this theory as it was originally held involved the idea that the lymphatics started in the periphery of the body and subsequently grew toward the veins. Huntington and McClure have not made any clear statement regarding the growth of the peripheral lymphatics from the center to the periphery. They say, "The first indications of the lymphatics appear in the region of the precardinal veins" ('06–08, p. 38), that is, they are centrally placed, but again they say, "The claim, made by Dr. Sabin and others, that no lymphatics make their appearance in the body before the jugular sacs are formed, can best be answered by asking for a definition of a lymphatic" ('10, p. 187). Thus while it is impossible to know how they stand on this point, the acceptance of the idea of the first lymphatics being centrally placed, joined to the theory of the mesenchymal origin of the ducts involves the conception of the constant addition of new structures at the growing tip. The

evidence that to the lymphatic are added connective tissue spaces is this, that in sections one can see a definite lymphatic vessel lined with an endothelium which is not complete but has a break which opens into the tissue spaces. The answer to this is plain. First, lymphatics which have been seen to be complete in the living tadpole's tail, have such breaks in the endothelium in preserved specimens. Secondly, in the skin of the embryo pig an injection watched under the microscope shows a complete intact endothelium, which may be explosively ruptured by increase of pressure. A piece of this skin which by injection on one side of the embryo can be shown to have intact endothelium, appears to have breaks in serial sections on the opposite uninjected side. The observations in sections are not enough to settle the time honored question of open and closed lymphatics. To prove any lymphatic vessels open one must either show an open vessel in the living, or show that an injection always runs over into the tissue spaces at the growing tip, which is not true. The evidence at hand on the general peripheral lymphatic vessels in the embryo is that they are closed. There is no question but that confusion will continue on this question until each investigator submits his methods to rigid tests. On the one hand we have a group of investigators who have availed themselves of the chance to study lymphatics (a) in the living, (b) by positive lymphatic and, as it were, negative vascular injections, and (c) by serial sections both of injected and of uninjected embryos. On the other hand, the other group studies sections of uninjected specimens alone. It is not to be wondered at that our conclusions differ. Serial sections do show isolated endothelial-lined lymphatic anlages, and they do show even in well fixed tissue breaks in the endothelial wall but the nature of endothelium can not be determined by sections alone.

We believe that it has been proved that the lymphatic endothelium is derived from the endothelium of blood vessels and that once so formed the lymphatic endothelium is specific and gives rise to the rest of the lymphatic endothelium. The evidence for this is (1) that the extent of the peripheral lymphatics recedes in smaller embryos to central lymphatics which are proved to be of

vascular origin by the fact that in slightly earlier stages they are an integral part of the blood vessels injecting with ease either through the arteries or the veins. (2) We think that the peripheral vessels arise from these primary sacs because injections into the sacs in successive stages run into wider and wider zones of lymphatic vessels and these injections show sprouts of endothelium, pointed and slender in rapidly growing zones, but rounded in zones which are not growing rapidly, and similar sprouts are well known to indicate the centrifugal method of growth in blood vessels. The appearance of these sprouts in specimens allows a logical inference of the centrifugal method of growth but does not constitute an absolute proof of such a method, but such proof is not wanting in watching the lymphatic capillaries as well as the blood capillaries grow in the living form. As seen in the living form, blood capillaries and lymphatic capillaries grow by the division of the nuclei and the extension of the protoplasm of the endothelial syncitium. Moreover, we have tested the method of reconstructing serial sections of uninjected specimens and have found out that the question of the nature of the growing tip of capillaries lies wholly within the limits of error of the method and hence reconstructions can not be accepted as evidence of the method of growth. Uninjected lymphatic or blood capillaries can not be completely reconstructed. Therefore it will be readily seen that those who have watched the process of growth in one living form and have found out by tests that all of the appearances interpreted as meaning another form of growth can be produced in this form by fixation will not accept the theory that lymphatics grow one way in amphibia and another way in reptilia or mammalia, nor one way at one stage of development and another way later, when the only evidence ever offered is that sections look as if it were so. The interpretation of sections fails as evidence against the observation of the living or injected specimens which show all of the lymphatics of the living.

Dr. Huntington has challenged me to define a lymphatic. I will gladly do so for I think that a clear definition is the logical result of the work of our laboratory. Lymphatics are modified veins. They are vessels lined by an endothelium which is derived

from the veins. They invade the body as do blood vessels, and grow into certain constant areas; their invasion of the body is, however, not complete, for there are certain structures which never receive them. The lymphatic capillaries have the same relation to tissue spaces as have blood capillaries. None of the cavities in the mesoderm such as the peritoneal cavity, the various bursae and serous cavities form any part of the lymphatic system. The lymphatic endothelium once formed is specific. Like blood vessels the lymphatics are for the most part closed vessels.

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THE BUCCAL MUCOUS MEMBRANE

JAMES CRAWFORD WATT

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SIX FIGURES

In 1863 Luschka noted the occurrence of villi on the lips of newborn children and described the lips as comprising two zones, the pars glabra, extending from the red border to the normal line of contact of the closed lips, and orally to this, the pars villosa bearing villi. The distinctness of the two zones apparently disappeared, however, within a month after birth, owing to the disappearance of the villi, but in 1895 Neustätter found that he could still distinguish the two zones in the child, after the disappearance of the villi, by differences in the structure of the mucosa. This led him to extend his observations to the adult with the result that he found that the differences occurring in the child persisted throughout life, the mucosa of the pars villosa being characterized by a much thicker epithelial layer and by much larger, irregular, vascular papillæ than were present in the pars glabra.

A little later Stieda ('99) made a more thorough study of the pars villosa and definitely determined the time of the appearance of the villi, his results in this direction being as follows: "The villosities of the upper and lower lip appear first in exceptional cases, in the fourth month (of intrauterine life), in the fifth month in 50 per cent, and in the sixth month in almost 75 per cent of cases. From the seventh month on they are invariably present." But Stieda's observations were not extended to the adult, nor did he perceive that the pars villosa extended considerably beyond the lip area. This was demonstrated by Malka Ramm ('05) who found that in the fetus the villi extended from the angle of

the mouth backward across the cheeks in a broad band, bounded above and below by an area in which the mucosa was quite smooth, the delimitation between the smooth and villous portions being a sharply defined zig-zag line.

At the suggestion of Professor J. Playfair McMurrich I made an examination of the mucosa of the adult cheek with the view of determining whether or not a distinction between the true mucous membrane zones and pars villosa, such as Neustätter had observed in the lips, also obtained in the cheeks throughout life. It seemed that the question might have some bearing upon the distribution of ectoderm and endoderm in the oral cavity and also in the morphology of the internal cheek pouches of various mammals (Brandt, '01). The present inaccessibility of the material necessary for such an extension of the investigation has prevented me following it out along these lines, but it has seemed advisable to present the results obtained from the material in hand.

This material consisted of the lips and cheeks of a normal adult man, dissected away so as to include the whole extent of the parts to their reflection on to the upper and lower gums, and also several similar specimens obtained from fetuses varying from two and a half to seven months old. For purposes of comparison the lips and cheeks of an adult collie dog, and of a fetal guinea-pig were also employed. The preparations were fixed either in formalin or Zenker's fluid, were imbedded in celloidin, and the sections were cut so as to include the whole vertical extent of lips or cheeks showing the mucosa in its whole extent from the upper to the lower gums, and these were stained partly in haematoxylin-eosin, and partly with Mallory's connective tissue stain.

The macroscopic appearances of the preparations were of little significance. On the lips of the older fetuses villi were present but apart from this fact the mucous membrane everywhere presented a smooth surface. It is worth while calling attention, however, to the fact that some people can distinguish with their tongue a difference in the feeling of the various parts of the lips and cheeks. The area corresponding to the pars vil-

losa feels velvety and even, while that between it and the gums is glabrous and almost lumpy. On the dog's cheek the central zone was more deeply pigmented than the zone above and below it, and this deeply pigmented strip was continuous with that on the inside of the lips.

The microscopic appearances seen in the sections are very characteristic, the structure of the adult human cheek agreeing exactly with that found in the adult lips by Neustätter, the region of the pars villosa being clearly distinguishable from the zones above and below it. In the zone next to each gum (figs. 1 and 3) the epithelium is of moderate thickness and quite uniform, the upper few layers of cells being squamous in character. The lower layer of the epithelium, resting on the submucous connective tissue, forms a regular, wavy or undulating line, with papillæ pushing up into it, these papillæ all being uniform both in size and shape. They are small, thin, and rounded at the top; they have about the same diameter from the base to the apex, and lie obliquely, usually pointing towards the center of the cheek. They are all fairly vascular, and some are much curved, so that the apex may be cut by a section which does not touch the base.

In the central zone, the pars villosa (fig. 2), there is a marked difference from the conditions described above. The epithelium here is very deep, being two and three times the thickness of that in the rest of the cheek, and the layers of squamous cells are much more numerous. Its lower or germinal layer is extremely irregular in outline, due to the varying sizes of the papillæ protruding into it, and these papillæ are several times the size of those in the other zones, and present a great variety of shapes, some being conical, some pyramidal, and some long and thin and of the same diameter throughout. The bases of most of them are very broad, while the apices are variable, some being very sharp and tapering, while others are rounded, or present expanded, knob-like ends. These papillæ are all very vascular and have large arterioles occupying their axes and surrounded by a basket of capillaries, peripheral to which are the efferent venules. None of the papillæ extend through the total thickness of the epithelium up to the free surface. Various measurements of these three

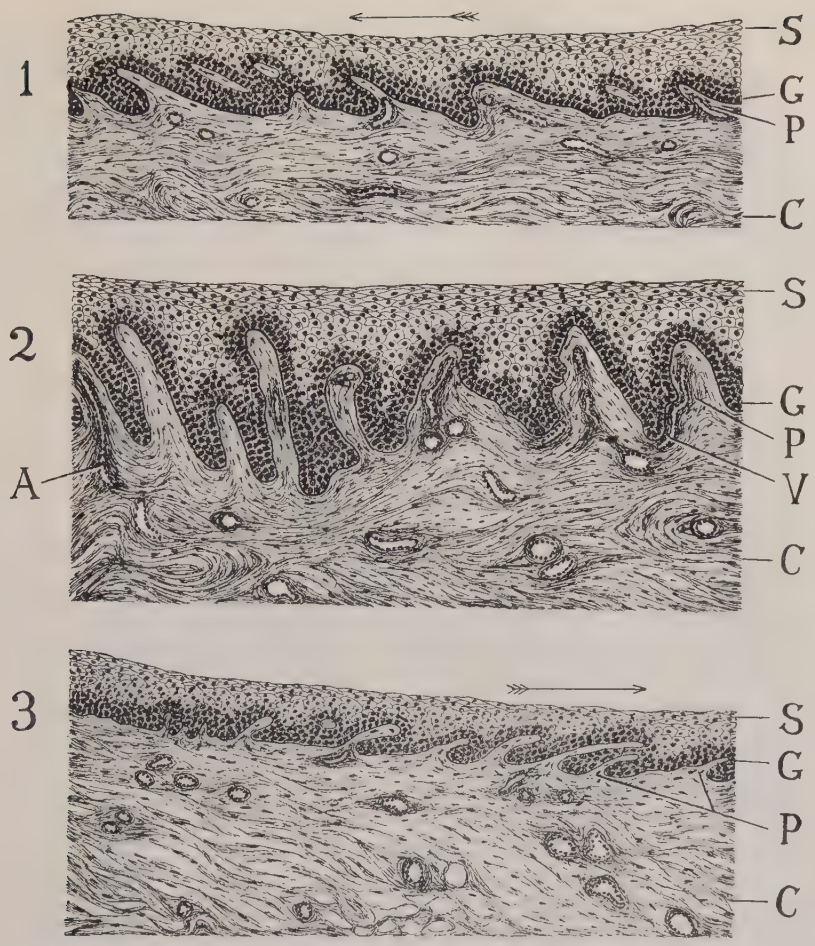
zones were taken for the purpose of comparison and these serve to demonstrate some of the differences very clearly.

TABLE 1

		ZONES NEXT GUMS	PARS VILLOSA
		microns	*microns*
Total depth of epithelium		150–175	170–300
Height of epithelium above papillae		80–100	60–120
Vertical height of papillae		25–100	100–200
Distance between apices of papillae		100–180	100–300
Diameter of papillae	apex	10–25	25–75
	middle	10–25	75–125
	base	25–100	100–300

The pars villosa occupies a half of the width of the cheek and the zone on each side of it a quarter. The transition from one area to the next is gradual, and yet it is quite distinct within the range of a very few papillæ.

The earliest fetal cheek examined was from a fetus between two and a half and three months old. The epithelium of the mucosa in this case was of the same thickness throughout the whole cheek and the germinal layer formed a straight line, showing no indentations by papillæ, these not yet having made their appearance. At a slightly later stage the epithelium suddenly becomes thinner in the immediate neighborhood of the gums, and papillæ are quite evident but appear to be equal in size and similar in shape over the whole cheek. At five months a decided difference begins to be apparent in the zones. There is a very narrow zone close to each gum in which the epithelium is thin and in which the papillæ are low and regular, while the rest of the cheek is covered by a very thick layer of epithelium with large, irregular, jagged papillæ protruding into it. In the lips of the fetus no villi are yet present but the pars glabra, pars villosa, and true mucous area back of this are all clearly distinguishable and present an appearance identical with that described by Neustätter for the lips of a newborn child immediately after the villi have disappeared. In fetuses of six and seven months,



Figs. 1–3 Cheek of adult man. Magnification × 75.

Fig. 1 Cross section of mucous membrane close to upper gum. Epithelium of ordinary thickness, upper layers squamous, lower layer of regular outline. Papillæ are regular, long, thin, of uniform thickness, and lie very obliquely.

Fig. 2 Cross section of mucosa in central zone,—pars villosa. Epithelium is very thick, shows many layers of squamous cells, germinal layer is very irregular. Papillæ are irregular, pyramidal, conical, or finger-like, with blunt, knobbed, or sharp apices. All are very vascular.

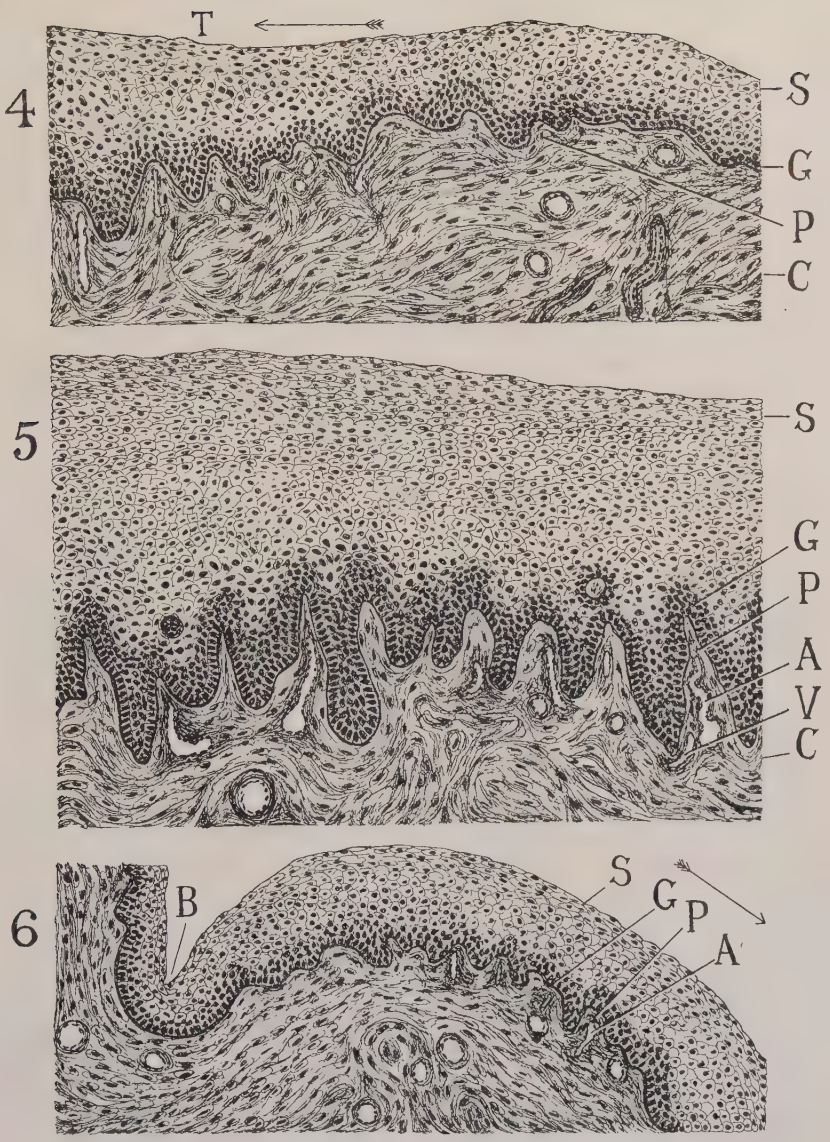
Fig. 3 Cross section of mucosa close to lower gum. Description is similar to fig. 1.

REFERENCE LETTERS, FIGURES 1 TO 6

S, squamous layers of epithelium; *G*, germinal layers of epithelium; *P*, papillæ; *A*, arteriole; *V*, venule; *C*, connective tissue; *T*, transition to pars villosa; *B*, bucco-alveolar fold. Arrow points to pars villosa.

while all the parts of the cheek have grown considerably, the two zones next to the gums occupy progressively more of the width of the cheek than they did in the earlier stages. In the newborn child and in the adult this proportion is still greater, so that in comparing the series it would appear as if the pars villosa represents the whole of the original mucous membrane of the cheeks and that the zones next to the gums are formed by growth and extension of tissue into the inner side of the cheek from the contiguous margins of the gums. The same is true for the corresponding areas of the lips, since they are identical in structure with those of the cheek, and form with them component parts of one structural entity. In the lips of the older fetuses mentioned above villi are present, extending above the general surface of the mucosa; they are covered by epithelium and have as a core the greatly enlarged papillæ of this region. In fetuses older than seven months the conditions found in the cheeks resemble those which have been thoroughly described by Malka Ramm ('05).

In the seven months fetus the structure of the buccal mucosa has reached a stage in which it closely resembles the permanent condition found in the adult, and at the same time no papillæ yet reach the surface of the epithelium, and there is no evidence of any villi being formed. The width of the cheek shows three zones, one in continuity with each gum, and between these two a central zone, the pars villosa. This last occupies three-quarters of the width of the cheek, the other two strips an eighth each respectively above and below this. In the fetuses I examined, I found the epithelium to be always deeper than in the corresponding situations in the adult, but whether this is invariably the rule or not, I cannot say. In the zones of true mucous membrane next to the gums (figs. 4 and 6) the epithelium is not very thick, the layers of squamous cells are few, and the papillæ are low, regular, uniform in size and shape, and also appear broader and blunter than in the adult. The lower border of the epithelium thus forms a gently undulating or wavy line. In the pars villosa (fig. 5) a great contrast to the above condition presents itself. The epithelium is two or three times as thick, and shows



Figs. 4–6 Cheek of human fetus. Magnification × 75.

Fig. 4 Cross section of mucosa close to upper gum. Epithelium moderately thick, with few squamous layers, lower germinal layer of regular wavy outline. Papillæ are low, regular.

Fig. 5 Cross section of pars villosa, previous to appearance of villi. Epithelium is very thick, has many layers of squamous cells, and germinal layer is extremely irregular. Papillæ are very large, irregular, pyramidal, conical, or rounded, with apices peaked, blunt or rounded.

Fig. 6. Cross section of mucosa close to lower gum. Description is similar to fig. 4. Part to left hand shows reflection on to gum.

many layers of squamous cells. Its lower border of germinal epithelium is most irregular in outline and large papillæ of variable size and shape project far up into the mucosa. They may be finger-like processes, or little hillocks, or pyramidal or conical in form, while they terminate either in blunt, rounded extremities, or in sharply pointed peaks. They are extremely vascular and comparatively large arterioles and venules can be seen entering and leaving them.

The table of measurements here appended gives a very good idea of the contrast between the zones.

TABLE 2

		ZONES NEXT GUMS	PARS VILLOSA
		microns	*microns*
Total depth of epithelium		180–210	350–480
Height of epithelium above papillae		100–160	250–350
Vertical height of papillae		30–50	100–200
Distance of tops of papillae apart		100–150	100–300
Diameter of papillae	apex	20–50	10–60
	middle	40–60	50–100
	base	100–120	100–350

The structure of the adult dog's cheek is in all respects similar to that of the adult human cheek. The same three zones occur and they are just as distinctively delimited and have precisely the same characteristics. Indeed, the transition from the one zone to the other is even sharper and more distinct than in man.

In the cheek of the fetal guinea-pig examined no papillæ were yet developed and the epithelial layer was quite smooth throughout. The structure of the buccal mucosa was that of one of the early stages seen in the human fetus, for in the region of the pars villosa, both on lips and cheeks, the epithelium had double the thickness that it had over the other zones.

The conclusions arrived at from consideration of the above data are:

1. In the cheek of the human child and adult, long after all villi have disappeared, the region of the pars villosa can be identified. It is distinguished from the zones next to the gums above

and below it, just as Neustätter showed it could be in the lips, by the increased thickness of its epithelium, and by the increased size, vascularity, and irregularity of the subjacent papillæ.

2. In both lips and cheeks, in the human fetus, for several weeks before any villi make an appearance, the pars villosa and the other zones in these parts may be all clearly recognized by the distinctive characteristics of their epithelium and papillæ.

3. The pars villosa appears to represent all of the mucous membrane of the lips and cheeks when they are first formed. During the development of the fetus the mucosa and submucosa of these parts grow both by increase in size of the pars villosa itself, and also by addition of tissue both above and below this area by an extension from the contiguous tissues of the upper and lower gums.

4. The pars villosa, with its distinctive characteristics is not restricted to the human species, but evidences of its existence are to be found both in fetal and adult stages in some of the lower animals; indeed, the area is even more clearly defined in the adult dog than in an adult man.

In conclusion I wish to offer my most sincere thanks to Professor J. Playfair McMurrich for supplying me with the necessary opportunities for this work, and also for the interest he has shown in its progress.

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A NOTE ON THE ANATOMY OF THE PULMONARY ARTERIES OF MAMMALS

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TWO FIGURES

Piana[1] was the first to describe a discontinuous or segmented musculature in the final ramifications of the pulmonary arteries (arterioles) of certain mammals. This condition is most pronounced in the ox. Here the tunica media consists of successive rings of smooth muscle connected by thin interannular spiral bands of similar muscle[2] (fig. 1). A like condition is said to obtain in the calf, pig, and sheep, but of very much lesser degree. In man, horse, cat, dog, and rabbit the pulmonary arteries are said to have the same structure as the arteries of other parts of the body, *i.e.*, their musculature is continuous.

While engaged upon a microscopic study of the lung of the guinea-pig, with a view to discovering some anatomic basis for the unique occurrence in this form of acute anaphylactic death, Schultz and Jordan[3] discovered a very pronounced segmented condition of the musculature of the pulmonary arteries. While this condition, peculiar to guinea-pig as far as was then known, was recognized as a possible contributory factor in the production of the immediate anaphylactic reaction, certain anatomic conditions of the secondary and tertiary bronchi were regarded as the primary factors. It seems probable, however, that the

[1]Piana, G. P.: Osservazioni comparative intorno alla struttura delle ultime diramazioni delle arterie pulmonari. Mem. della Accad. delle Sci. dell, Istituto di Bologna. s. IV. Tome 1, 1880, pp. 417-420.

[2]Previously noted by H. Müller and by Ranvier; cf. Piana.

[3]Journ. Pharm. and Exp. Therap., vol. 2, no. 4.

relatively thick and segmented musculature of the pulmonary arteries is of more importance in this connection than was formerly supposed.

Compared with the illustrations of Piana for the ox, the muscle segments of the pulmonary arteries of the guinea-pig are much thicker. Nor are they separated one from the other by as wide intervals; nor are they connected by spiral muscle bands.

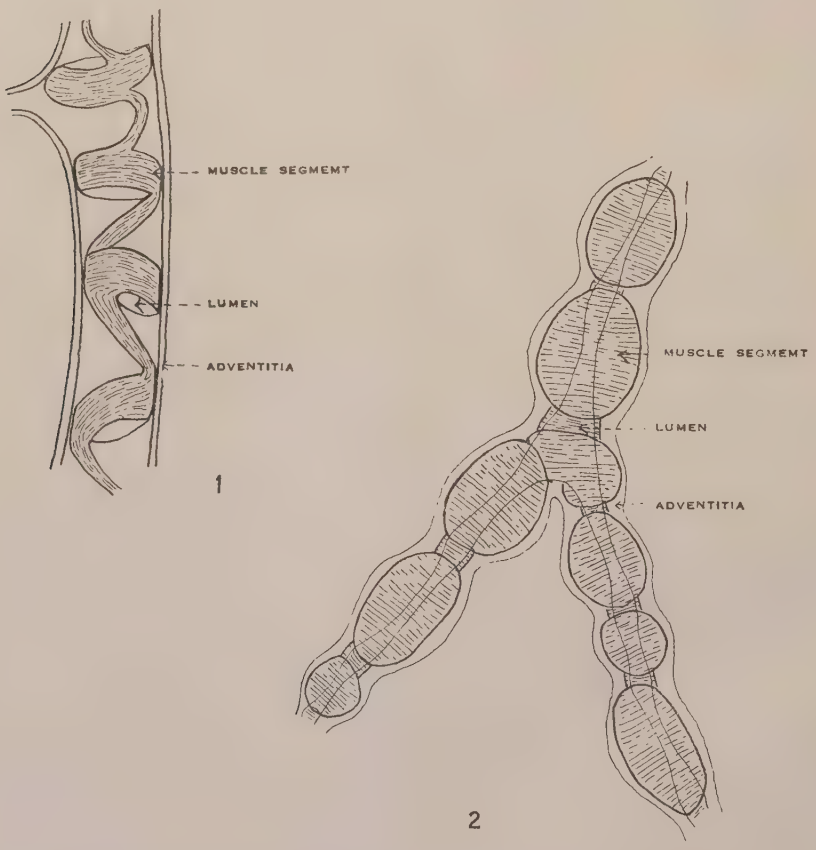

Fig. 1 Semi-diagrammatic illustration of small branch of pulmonary artery of ox (after Piana). × 100.

Fig. 2 Semi-diagrammatic illustration of dividing small branch of pulmonary artery of guinea-pig. Pulmonary arterioles of opossum are almost identical. × 75.

The muscle segments are spherical or oval (longer and shorter) bodies encircling the vessel lumen. They consist of circularly disposed muscle fibers. The small interval between two segments is formed by a thin layer of circularly disposed smooth muscle fibers continuous with the inner layer of the segments.

Moreover, contrary to Piana's observations, according to which the metameric condition of the musculature of the pulmonary arteries of the ox, sheep and pig is confined to the terminal ramifications, in the guinea-pig this condition obtains as far as the root of the lung, but in progressively less degree.

A study of the pulmonary arteries of the mouse reveals the fact that here the tunica media (muscularis) is thin and continuous. The same is true also with respect to the bat and chipmunk.

In the lung of the opossum conditions respecting the pulmonary arteries are identical with those in the lung of the guinea-pig, except that the segments are somewhat longer, a condition probably incidental to the somewhat coarser structure of the lung as a whole. Here, as in the guinea-pig, the muscle segments are relatively very thick, consisting of circularly disposed smooth muscle fibers; the intersegmental spaces are very narrow and lack the spiral muscle bands characteristic of the ox, but are spanned by a thin layer of smooth muscle; and the segmented condition persists in a decreasing degree to the root of the lung. In both guinea-pig and opossum the arteriole resembles a string of muscle beads. Peripheral to the muscle segments or 'beads' is a tunica adventitia of approximately half the width of the discontinuous musculature.

In view of the extensive use of guinea-pigs for physiologic work it seemed important to call special attention to the peculiar condition of the musculature of the pulmonary arteries. Certain respiratory phenomena, under various experimental or pathologic conditions, may find a partial explanation in a constriction of this musculature, causing a more or less complete occlusion of the lumen and consequent rapid or gradual asphyxia.

Piana regarded the muscle segments as a mechanism for regulating or 'moderating' the velocity of the current of the blood

passing to the capillary network of the pulmonary alveoli. It is obvious, however, that this anatomic condition is not essential since many mammals lack it. It seems a real disadvantage since any vaso-constricting agent may produce death.

It is an interesting fact that this condition, as far as is known, is limited to the lower mammals; and it becomes progressively less as we ascend in the scale (opossum, guinea-pig—Jordan; ox, sheep, pig—Piana) and is entirely wanting in the higher forms (horse, cat, dog, man, rabbit—Piana; mouse, bat, chipmunk—Jordan).

The condition would thus seem to be a primitive one, perhaps lost by process of natural selection in the evolution of higher forms. It is also an interesting fact that, as far as has been fully tested, acute anaphylactic death cannot be produced in those animals that lack the condition (e.g., dog, cat, rabbit, mouse), whereas sensitized[4] guinea-pigs, which possess it in an extreme degree of development, succumb (by asphyxia) to a proper second injection of horse serum in from three to five minutes. If this surmise of a close relationship between an unusually thick and discontinuous musculature of the pulmonary arteries and the immediate reaction of anaphylaxis is correct, the opossum should furnish a good object for the further study of the phenomenon of anaphylaxis.

[4]The initial dose of horse serum renders the smooth muscle generally hypersensitive to a second injection—Schultz: Journ. Pharm. and Exp. Therap., vol. 1, no. 5.

A STUDY IN SURFACE ANATOMY WITH SPECIAL REFERENCE TO THE POSITION OF THE UMBILICUS

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ONE FIGURE

The following study is based on a series of measurements taken at the University of California during the year 1910–1911. The subjects measured were the entering students, the majority of whom were freshmen. Cordial thanks are to be expressed to Dr. Eleanor S. Bancroft and to Dr. W. A. Sawyer, the medical examiners, for their assistance and coöperation.

One thousand students were measured, of whom 650 were men and 350 were women. The following measurements[1] were taken: the total height; the distance from the supra-sternal notch to the superior border of the symphysis pubis; the distance from the sternal notch to the umbilicus, both standing and lying; the distance from the umbilicus to the symphysis, both standing and lying; the distance between the anterior superior iliac spines; the distance from the superior border of the symphysis to this line standing and lying; the distance from the umbilicus to this line, standing and lying; the length of the right and left leg, measured from the anterior superior iliac spine to the center of the external malleolus; the length of the right and left arm, measured from the acromion process to the tip of the styloid process of the radius; and the distance from the superior border of the symphysis to the floor. The measurements on the body

[1] These measurements are given in full in the copy of this article on file in the Library of the University of California.

were made with calipers, and on the limbs with steel tape. It must be remembered that the subjects measured were *young* adults, the average age being between nineteen and twenty.

The main object of the research was to ascertain, if possible, the true position of the umbilicus in relation to dependable landmarks, and to note any differences in location caused by sex, weight, or position.

The literature on this subject is far from satisfactory. Charpy, who measured fifty subjects, states that the position of the umbilicus varies with age, being a little above the midpoint of the total body height in the newborn, at the midpoint at the age of two years, and below that point in the adult. His measurements were taken from the xiphoid process to the symphysis, from the xiphoid process to the umbilicus, and from the symphysis to the umbilicus. He reached the following conclusions: 1) that a woman's abdomen is longer than a man's; 2) that the xipho-umbilical distance is essentially the same in men and women (relatively to the whole height); 3) that the umbilico-pubic distance is relatively greater in women than in men; 4) that the abdomen of the infant is much longer in proportion than that of the adult. Giovanni attaches a great clinical importance to these facts, making the following statements:

> Pour lui la longueur abdominale indique l'intensité du développement embryogénique de tube digestif; la longueur xipho-ombilicale est proportionnelle au volume atteint par l'estomac, le foie, la rate et le pancréas dans leur évolution jusqu'à l'âge adulte; la longueur ombilico-pubienne mesure l'importance de l'intestin.—Ces propositions attendent un contrôle anatomique précis.

Testut reports on some measurements taken by Tillaux on thirteen adult subjects. He found the average height to be 167 cm., and the average distance from the umbilicus to the crown of the head was about 64 cm., or approximately 20 cm. below the midpoint of the total height of the subject.

Cunningham places the position of the umbilicus below the midpoint of the line between the infra-sternal notch and the symphysis pubis, a little below the level of the highest points of the iliac crest, and opposite the middle of the body of the fourth lumbar vertebra. He notes that in the obese and in cases where there is lack of tonicity of the abdominal muscles, the umbilicus may occupy a position below the normal level.

Morris places the umbilicus at the level of the cartilage between the third and fourth lumbar vertebrae, at the point corresponding to the tip of the third lumbar spine, 2.5 cm. above the level of the highest points of the iliac crests, and 1.8 to 2.5 cm. above the bifurcation of the aorta.

Campbell agrees with Morris, and Gray makes the position correspond to the level of the highest points of the iliac crests. Other anatomists state that the umbilicus is a little below the center of the linea alba.

From all these varying statements it may be inferred that the individual variation is marked, and that a definite average has not as yet been worked out. However, one cause of the varying statements is probably the fact that the landmark ordinarily used for the upper measurement was the tip of the xiphoid process or else the infra-sternal notch, and since the length of the sternum varies greatly, and since the xiphoid process is exceedingly variable, these landmarks are not sufficiently definite. Hence in the following study the measurements were taken from the supra-sternal notch.

The following are the averages of all the measurements. The age, height, and weight of all could not be ascertained.

	FOR 272 WOMEN	FOR 486 MEN
Age	19.75	19.33
Weight	54.92 Kg.	62.4 Kg.
	121.09 lbs.	137.57 lbs.
Height	162.65 cm.	173.18 cm.

	FOR 350 WOMEN	FOR 650 MEN
	cm.	*cm.*
Sternal notch to symphysis	49.45	52.08
Sternal notch to umbilicus { standing	35.55	37.48
Sternal notch to umbilicus { lying	33.88	36.38
Umbilicus to symphysis { standing	15.60	15.55
Umbilicus to symphysis { lying	15.72	15.65
Distance between ant. sup. iliac spines	22.66	21.5
Symphysis to line between spines { standing	10.07	8.62
Symphysis to line between spines { lying	8.08	8.64
Length of leg { right	86.19	91.89
Length of leg { left	86.15	91.47
Symphysis to floor (for only 40 women)	80.21	87.63
Length of arm { right	51.29	56.51
Length of arm { left	51.24	56.44

Comparing these results with Charpy's measurements of the distance from the umbilicus to the symphysis, there is less difference between men and women than he found.

Comparing with the measurements of Tillaux, the position of the umbilicus in relation to the whole height is lower by three to four centimeters. The fact that he worked with but a limited number of subjects may account for this difference.

The following ratios and comparisons are obtained from the averages of the figures:

Age: women average 5 months older than the men.
Weight: women average 7.48 Kg. or 11.9 per cent lighter than the men.
Height: women average 10.43 cm. or 6.08 per cent shorter than men.

In the following measurements, wherever a comparison is made between men and women, the average is given in parentheses, followed by the relative average; that is, the average in proportion to the height, regarding the whole height as 100. Thus, $49.45 : 162.65 :: x : 100$, where the average distance from the sternal notch to the symphysis is 49.45, the average height 162.65, and x the relative distance from the notch to the symphysis.

(1) Sternal notch to symphysis:
Women....(49.45) 30.40
Men.....(52.08) 30.07

0.33, difference

This distance on men thus averages 0.33 cm. or 1.08 per cent less than on women.

(2) Sternal notch to umbilicus:

Standing			*Lying*		
Women....	(35.55)	21.8	Women....	(33.88)	20.8
Men.....	(37.48)	21.6	Men.....	(36.38)	21.0
		0.2			-0.2

On men standing, this distance is .2 cm. or .9 per cent less than on women.
On women lying, this distance is .2 cm. or .95 per cent less than on men.
On women lying, the distance is 1.67 cm. or 4.69 per cent less than when standing.
On men lying, the distance is 1.10 cm. or 2.93 per cent less than when standing.

(3) Umbilicus to symphysis:

Standing			*Lying*		
Women....	(15.60)	9.59	Women....	(15.72)	9.66
Men.....	(15.55)	8.97	Men.....	(15.65)	9.03
		0.62			0.63

On men standing, this distance is .62 cm. or 6.3 per cent less than on women.
On men lying, this distance is .63 cm. or 6.5 per cent less than on women.
On women standing, the distance is .12 cm. or .75 per cent less than when lying.
On men standing, the distance is .10 cm. or 63 per cent less than when lying.

(4) Distance between the anterior superior iliac spines:

Lying		
Women....	(22 66)	13.9
Men.....	(21.5)	12.4
		1.5

On men this distance is 1.5 cm. or 10 8 per cent less than on women.

(5) Symphysis to this line between the iliac spines:

Standing			*Lying*		
Women....	(10.07)	6.19	Women....	(8.08)	4.96
Men.....	(8.62)	4.96	Men.....	(8.64)	4.97
		1.23			-0.01

On men standing, this distance is 1.23 cm. or 19.8 per cent less than on women.
On women lying, this distance is .01 cm. or .2 per cent less than on men.
On women lying, the distance is 1.99 cm. or 19.7 per cent less than standing.
On men standing, the distance is .02 cm. or .23 per cent less than when lying.

(6) Umbilicus to line between spines:

Standing			*Lying*		
Women....	(5.85)	3.59	Women....	(7.58)	4.66
Men.....	(6.95)	4.01	Men.....	(6.88)	3.95
		-0.42			0.71

On women standing, this distance is 0.42 cm. or 10.4 per cent less than on men.
On men lying, this distance is 0.71 cm. or 15.2 per cent less than on women.
On women standing, the distance is 1.73 cm. or 22.8 per cent less than lying.
On men lying, the distance is 0.07 cm., or 1.0 per cent less than when standing.

The following tables show the ratios existing between the distances from the umbilicus to the sternal notch and to the symphysis. From these ratios it is seen that the umbilicus is situated approximately two-thirds of the distance from the notch to the symphysis.

Women

Lying	Standing
S.N. 33.88 U. 15.72 S.	S.N. 35.55 U. 15 60 S.
49.60	51.55
S. N. to U. : S.N. to S. : : 1: 1.46	1: 1.43
U. to S. : S.N. to U. : : 1: 2.15	1: 2.27
U. to S. : S.N. to S. : : 1: 3.15	1: 3.27

Men

Lying	Standing
S.N. 36.38 U. 15.65 S.	S.N. 37.38 U. 15 55 S.
52.03	53.03
S. N. to U. : N. to S. : : 1: 1.43	1: 1.41
U. to S. : N. to U. : : 1: 2.32	1: 2.41
U. to S. : N. to S. : : 1: 3.32	1: 3.41

In these ratios it is seen that the distance from the notch to the umbilicus bears to the whole distance from the notch to the symphysis a slightly larger ratio in women than in men. Position has a slight influence on the location of the umbilicus, for in both sexes the ratio is less when lying and greater when standing indicating that the umbilicus is slightly lower when standing.

The following tables show, similarly, the ratios existing between the distances from the line between the anterior superior iliac spines to the symphysis pubis, and to the umbilicus. On women, the distance from the umbilicus to the line is a little more than one-third of the distance from the umbilicus to the symphysis when standing, and just about one-half of the distance when lying down. On men, this distance is between one-half and one-third of the whole distance between the umbilicus and the symphysis, and is practically the same for standing and lying. This latter difference may be due to the fact that with women the abdomen is usually more protruding, and the muscles more lax than in men.

Women

Standing	Lying
U. 5.85 L. 10.07 S.	U. 7.58 L. 8.08 S.
15.92	15.66
U. to L. : U. to S. : : 1: 2.72	1: 2.06
U. to L. : S. to L. : : 1: 1.72	1: 1.06
S. to L. : U. to S. : : 1: 1.58	1: 1.93

Men

U. 6.95 L. 8.62 S.	U. 6.88 L. 8.64 S.
15.57	15.52
U. to L. : U. to S. : : 1: 2.24	1: 2.25
U. to L. : S. to L. : : 1: 1.24	1: 1 25
S. to L. : U. to S. : : 1: 1 8	1: 1.79

To ascertain if weight makes any radical difference in these relations, four different groups were selected: fifty heavy and fifty light women, and fifty heavy and fifty light men. It must be borne in mind, however, that these extremes are only relative, none of the subjects being really obese.

The following are the averages thus obtained, compared with the total average:

Women

	WEIGHT	HEIGHT	N. TO U.		U. TO S.		S. TO L.		U. TO L.	
			(*st.*)	(*ly.*)	(*st.*)	(*ly.*)	(*st.*)	(*ly.*)	(*st.*)	(*ly.*)
Average	121.0	162.65	35.55	33.88	15.60	15.72	10.07	8.08	5.85	7.58
50 heavy	142.42	161.8	35.88	34.26	15.56	16.09	10.32	8.01	5.76	7.77
50 light	102.67	160.39	34.96	33.76	15.54	15.52	9.66	8.00	5.99	7.32

Men

Average	137.57	173.18	37.48	36.38	15.55	15.65	8.62	8.64	6.95	6.88
50 heavy	160.70	171.95	38.07	36.83	15.61	15 93	8 87	9 06	6 97	6 83
50 light	121.54	175.10	37.10	36.15	15.92	16.13	8.60	8.62	7.33	7.35

In the following tables the ratio may be compared:

Position of umbilicus

Women:

	STANDING			LYING		
	Average	Heavy	Light	Average	Heavy	Light
N. to U. : N. to S.	1:1.43	1:1.43	1:1.44	1:1.46	1:1.46	1:1:46
U. to S. : N. to U.	1:2.27	1:2.30	1:2.25	1:2.15	1:2.12	1:2.17
U. to S. : N. to S.	1:3.27	1:3.3	1:3.25	1:3.15	1:3.12	1:3.17

Men:

N. to U. : N. to S.....	1:1.41	1:1.41	1:1.42	1:1.43	1:1.43	1:1.44
U. to S. : N. to U.....	1:2.41	1:2.43	1:2.33	1:2.32	1:2.31	1:2.24
U. to S. : N. to S.....	1:3.41	1:3.43	1:3.33	1:3.32	1:3.31	1:3.24

Position of line between spines

Women:

U. to L. : U. to S.....	1:2.72	1:2.78	1:2.61	1:2.06	1:2.03	1:2.09
U. to L. : S. to L.....	1:1.72	1:1.78	1:1.61	1:1.06	1:1 03	1:1.09
S. to L. : U. to S.....	1:1 58	1:1 54	1:1 62	1:1 93	1:1 97	1:1.91

Men:

U. to L. : U. to S... ..	1:2 24	1:2.27	1:2.17	1:2.25	1:2.32	1:2.17
U. to L. : S. to L.....	1:1.24	1:1.27	1:1 17	1:1.25	1:1.32	1:1.17
S. to L. : U. to S.....	1:1.8	1:1.78	1:1.85	1:1.79	1:1.75	1:1.85

Differences between standing and lying

	AVERAGE		HEAVY		LIGHT	
Notch to umbilicus:						
Women	*Cm.*	%	*Cm.*	%	*Cm.*	%
Lying less than standing by.....	1.67	(4.69)	1.67	(4.69)	1.20	(3.43)
Men						
Lying less than standing by.....	1.10	(2.93)	1.24	(3.25)	0.95	(2.56)
Umbilicus to symphysis:						
Women						
Standing less than lying by.....	0.12	(0.76)	0.53	(3.29)	0.02	(0.12)
Men						
Standing less than lying by.....	0.10	(0.63)	0.32	(2.00)	0.21	(1.3)
Symphysis to line:						
Women						
Lying less than standing by.....	1.99	(19. 7)	1.99	(19.7)	1.66	(17.1)
Men						
Standing less than lying by.....	0.02	(0.23)	0.19	(2.09)	0.02	(0.23)
Umbilicus to line:						
Women						
Standing less than lying by.....	1.73	(22.80)	2.01	(25.8)	1.33	(18.1)
Men						
Lying less than standing by.....	0.07	(1.0)	0.14	(2.0)	−0.02	(.027)

From all of these tables the following conclusions may be drawn regarding the influence of a fatty deposit in the abdominal region: the position of the umbilicus in relation to the notch and symphysis was practically the same for all three sets of averages; the position of the line between the spines was somewhat lower than average in the heavy, and higher than average in the light, which would indicate a slight sagging of the abdominal wall at that region. This difference is more noticeable in women than in men, and the difference between standing and lying is also greater in women than in men.

The other measurements taken present some interesting features. As has already been stated, the width of the body, that is the distance between the anterior superior iliac spines, is proportionally much greater in women than in men. The relative difference is 1.5 cm. or 10.8 per cent, the difference being due to the relatively wider pelvis in women.

On men the leg is slightly longer in proportion to the distance from the notch to the symphysis, than it is on women.

Women.....N. to S.: R. leg, : : 49.45, : 86.19, or, 1 : 1.74
Men.....N. to S.: R. leg, : : 52.08, : 91.89, or, 1 : 1.76

The ratio of the distance from the symphysis to the floor, to the length of the right leg is greater in women than in men, due to the wider pelvis.

Women.....S. to F.: R. leg, : : 80.21, : 86.19, or, 1 : 1.07
Men.....S. to F.: R. leg, : : 87.63, : 91 89, or, 1 : 1 04

The length of the arm in relation to the distance from the notch to the symphysis, is slightly greater in men than in women.

Women.....N. to S.: R. arm, : : 49.45, 51.29, : or, 1 : 1 03
Men.....N. to S.: R. arm, : : 52.08, 56.51, : or, 1 : 1.08

The leg is longer in proportion to the length of arm on women than on men.

Women.....Arm: leg, : : 51.29, : 86,19, or, 1 : 1.68
Men.....Arm: leg, : : 56.51, : 91.89, or, 1 : 1.62

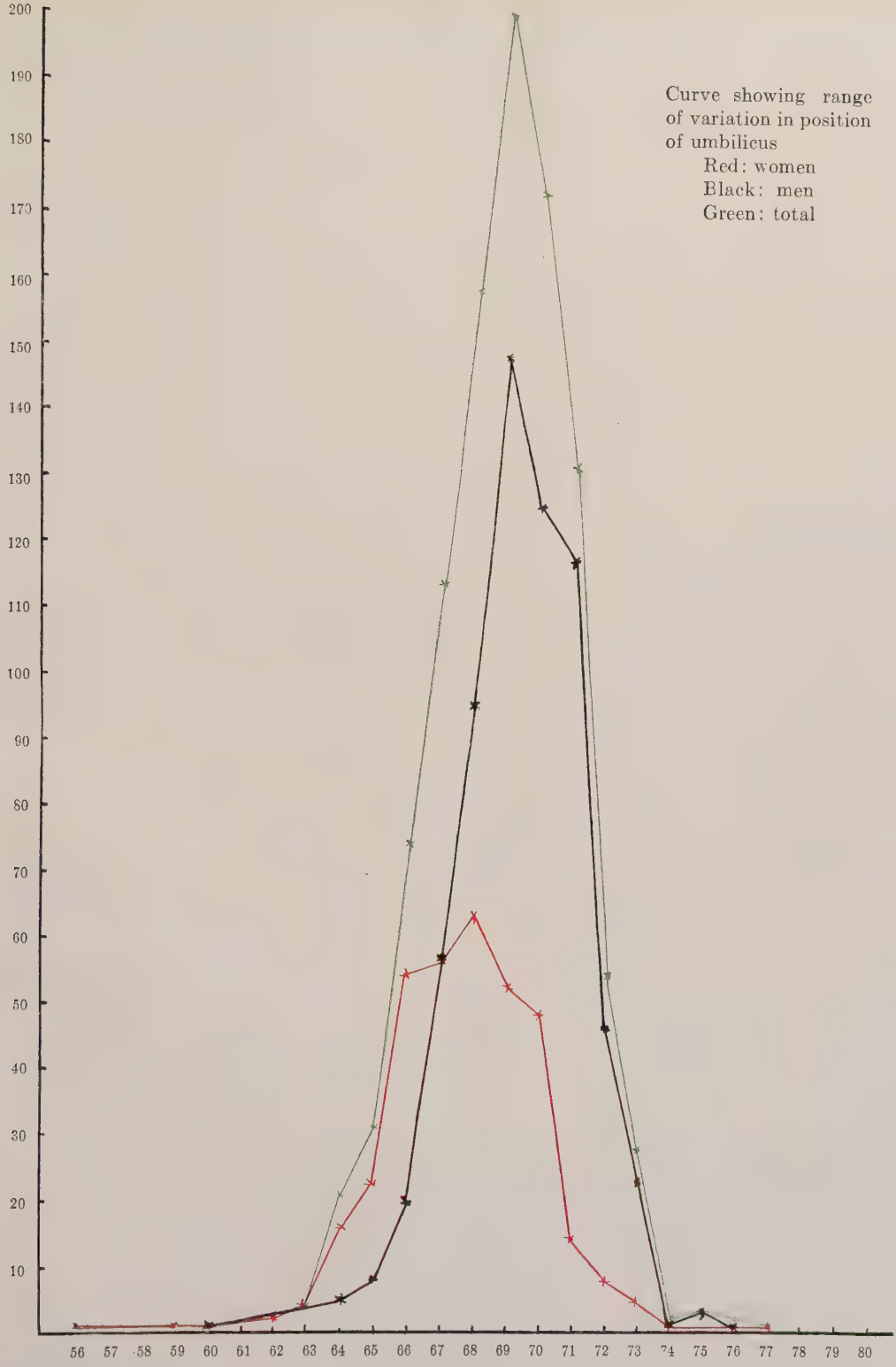
The left arm averages shorter than the right arm, and the left leg than the right leg on both men and women.

Women.....Left leg 0.04 cm. shorter; left arm 0.05 cm. shorter
Men .....Left leg 0.42 cm. shorter; left arm 0.07 cm. shorter

With relative measurements, in women the leg is shorter than in men by .07 cm.; the arm by 1.1 cm.

Regarding the range of variation in the position of the umbilicus, on men the greatest distance from the sternal notch to the umbilicus, in relation to the total distance from the sternal notch to the symphysis, is 76 per cent or more than three-fourths; the least is 60 per cent, or less than two-thirds. On women the greatest is 77 per cent and the least 56 per cent. The curve shows this range of variation, and also shows that the average for this distance is 68 per cent for women, and 69 per cent for men, or a little more than two-thirds.

To summarize, the conclusions reached in this study in regard to the position of the umbilicus are as follows: 1) that the umbilicus is situated approximately two-thirds of the distance from the supra-sternal notch to the symphysis; 2) that this fraction varies from more than three-fourths to less than two-thirds; 3) that when standing, the umbilicus is slightly lower than when lying down, a difference more marked on women than on men.


Curve showing range of variation in position of umbilicus
Red: women
Black: men
Green: total
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80
Percentage N. to U. / N. to S.

A CONTRIBUTION TO THE STUDY OF THE CEREBRAL CORTEX IN MAN

E. LINDON MELLUS

From the Anatomical Laboratory, Johns Hopkins University

EIGHT FIGURES

As one progresses in the study of the histology of the cortex cerebri, the subject, instead of becoming simpler and more easily understood, becomes more and more complex and difficult to arrange in conformity with present ideas and theories.

An exact knowledge of cerebral localization is desirable from every point of view, but in the opinion of many thoughtful investigators the tendency to localize function in the various cortical areas has gone much farther than is warranted.

The location of the speech function is still a matter of active controversy, although most clinicians are content to accept a centre for motor speech, and a series of centres, more or less indefinite it is true, for sensory speech—or more exactly, for the reception and elaboration of sensory impressions which make speech possible. The location of these centres in the left hemisphere, except in the case of left-handed individuals, is generally conceded, though there is still an occasional objection that the influence of the right hemisphere has been too much overlooked. In this connection the comparative study, here presented, of the cortex of the posterior portion of the third frontal convolution in the two hemispheres seems to have a special significance.

A comparative study of the cell lamination of this area in three brains shows a remarkable excess in favor of the left hemisphere. In the accompanying illustrations the percentage by which the left side exceeds the right is shown in the first, second

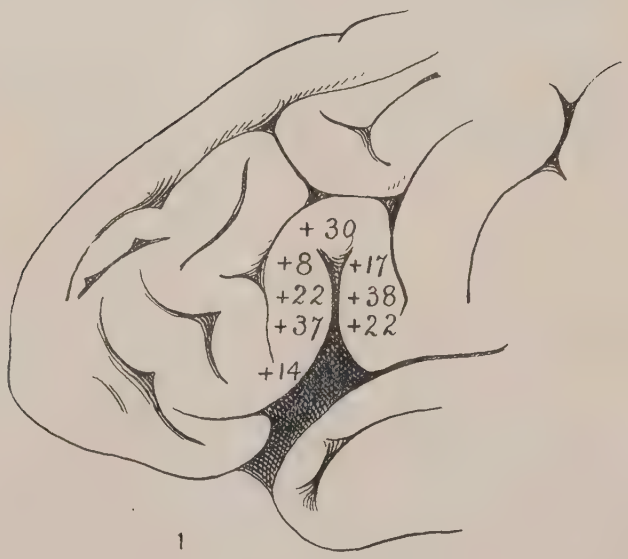
and third layers as well as in the total depth of cortex. Two of these brains—nos. 3339 and 3491—were obtained at the autopsy of patients who died in the Johns Hopkins Hospital. Each of these was the brain of an adult white woman with no history of mental disease, while the third, no. 250, was taken from the Anatomical Collection, and no history of either age, sex or race could be obtained.

In each case careful drawings were made of the convolutions and sulci of the two hemispheres upon which were recorded the exact location of the portions of cortex examined. Care was taken to have each segment cut at a right angle to the surface and to embrace as nearly as possible the entire convolution. The tissue was imbedded in parafin, cut in sections 20 microns in thickness and stained with Thionin. Camera lucida drawings were then made of the cortex under a magnification of 225 diameters at points corresponding in the two hemispheres.

A reference to the illustrations will show the usual variation in the configuration of the external surface of the right and left hemispheres as well as in different brains. The percentage of excess was reckoned from measurements of the drawings, and the illustrations show the area occupied by the cortex which was developed on the left side in excess of the right in each case. The increased depth of the three external layers is not quite symmetrical in the several cases, but the increase is certainly remarkable and significant. The boundary line between the fourth and fifth layers was too indefinite to give satisfactory measurements, and they were therefore confined to the three outside layers and to the entire depth of the cortex.

Other areas of the cortex have not yet been carefully compared, but a superficial study of the posterior portions of the first and second temporal convolutions in one brain shows practically the same excess in depth of the cell-layers of the left hemisphere over the right as above noted in the third frontal. A comparative study of the cortex of the two hemispheres in the brains of individuals of known mental ability should furnish a key to a much more precise science of localization than we yet possess.

In this connection the study of the brains of children and young adults should furnish much valuable data for the study of the development of special areas. The time and labor necessary for the prosecution of such an investigation is so great that it would appear to be a most promising field for a number of workers whose results might be correlated by a central committee, as has already been attempted in other lines of neurological investigation.



1

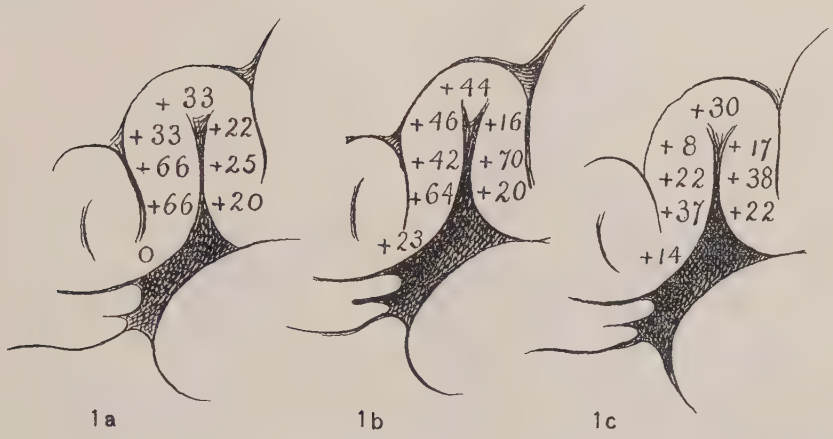
Fig. 1 Anterior portion external surface of left hemisphere, Brain 3339. The figures placed around the ascending ramus of the Sylvian fissure indicate the percentage of excess of the total depth of cortex upon the left side over corresponding points upon the right side. Thus, + 30 means that the total depth of cortex at that point in the left hemisphere is as 130 to 100 at the corresponding point in the right hemisphere (figs. 7 and 8).

Fig. 1a Represents the excess in depth of the external or first layer in the left hemisphere over corresponding points in the right hemisphere. *0*, means that the two sides were equal at that point.

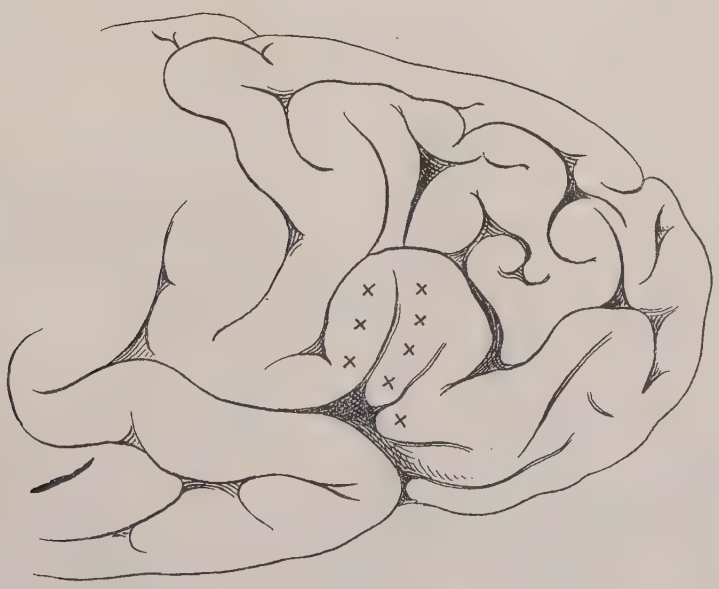
Fig. 1b The excess in depth of the outer pyramidal or second layer in the left hemisphere over the right.

Fig. 1c The excess in depth of the granular or third layer in the left hemisphere over the right.

Fig. 2 Anterior portion external surface of the right hemisphere, Brain 3339. The crosses are placed at points assumed to correspond to the points represented in fig. 1.



1a 1b 1c



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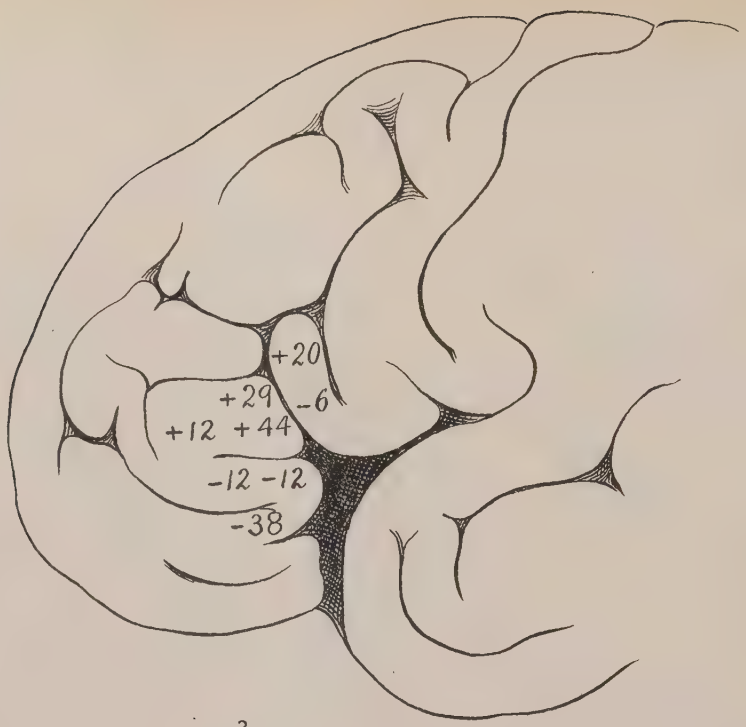

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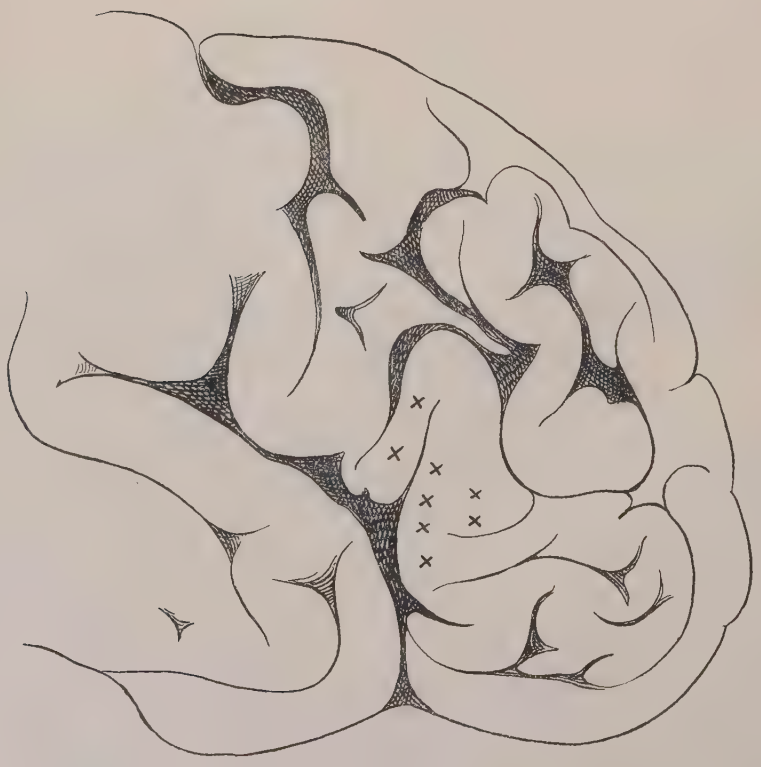

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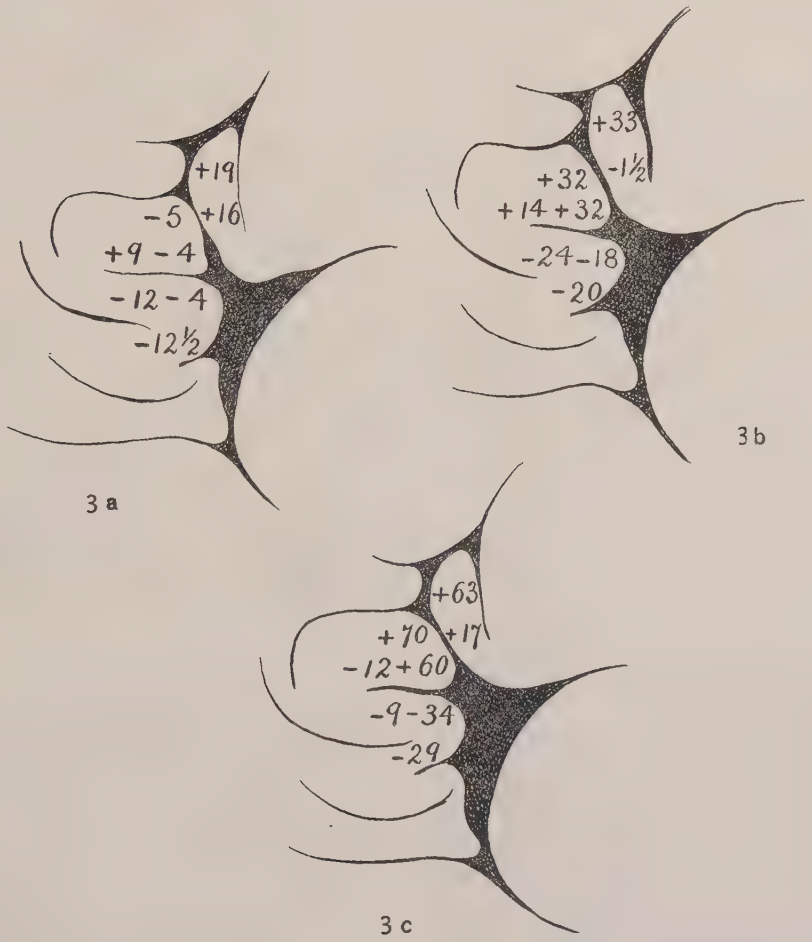


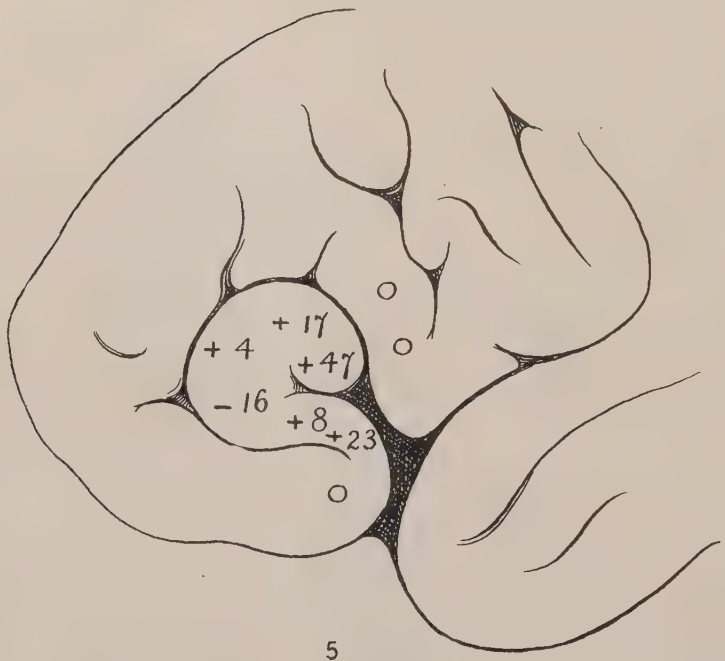
Fig. 3 Anterior portion external surface of left hemisphere, Brain 3491. The numerals represent the comparative depth of the entire cortex at points indicated. The plus sign means percentage of excess in the left hemisphere: the minus sign the excess in the right.

Fig. 3a The percentages in the depth of the first or external layer.

Fig. 3b The percentages in the depth of the outer pyramidal or second layer.

Fig. 3c The percentages in the depth of the third or granular layer.

Fig. 4 Anterior portion external surface of right hemisphere, Brain 3491, showing points assumed to correspond to points indicated in fig. 3.



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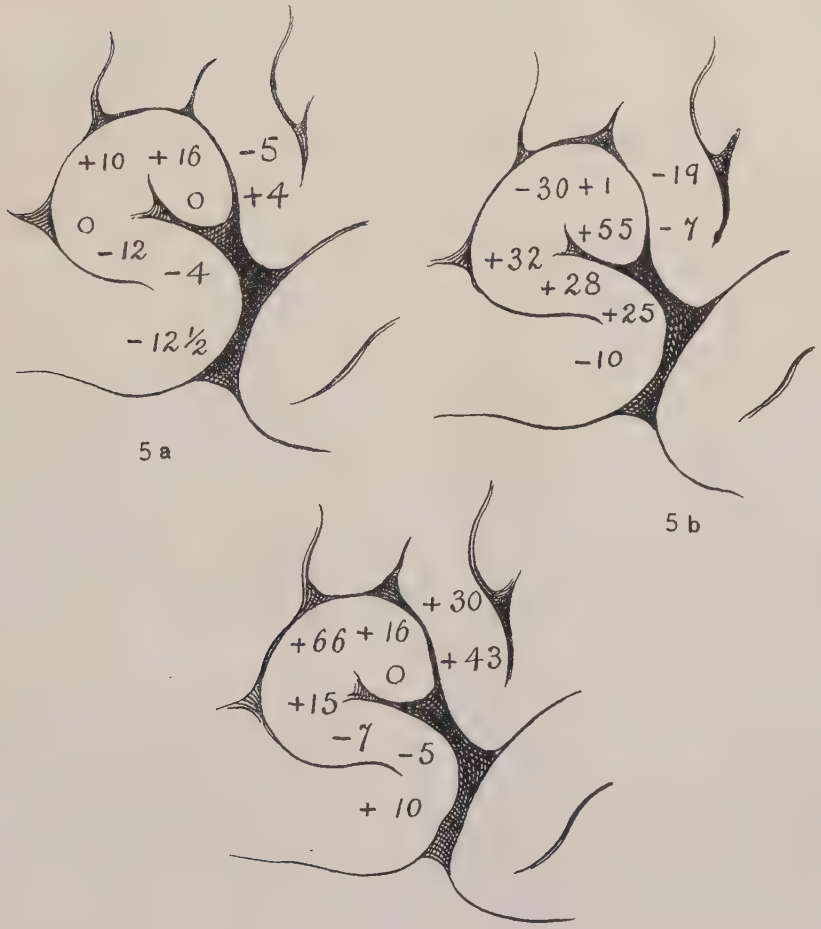


Fig. 5 Anterior portion external surface of the left hemisphere; Brain 250 showing the percentage of excess in the depth of the cortex, in the two hemispheres at points indicated.

Fig. 5a The percentages in the depth of the first or external layer.

Fig. 5b The percentages in the depth of the second or outer pyramidal layer.

Fig. 5c The percentages in the depth of the third or granular layer.

Fig. 6 Anterior portion external surface right hemisphere, Brain 250, showing points assumed to correspond to those indicated in fig. 5.

Fig. 7 Camera lucida drawing of the cortex at the highest point represented in fig. 1, Brain 3339. Drawing made at magnification of 225 diameters; reduced to ¼. (Figs. 7 and 8 on following page.)

Fig. 8 Camera ludica drawing of the cortex at the point in the right hemisphere. Brain 3339. Assumed to correspond to the drawing from the left (fig. 7). Magnification and reduction same as fig. 7.

7

8

SOME NEW LABORATORY FURNISHINGS

RALPH EDWARD SHELDON

The School of Medicine, University of Pittsburgh

FOUR PLATES

In furnishing the new laboratories of histology, embryology and neurology in the University of Pittsburgh Medical School, some arrangement was sought whereby all the working equipment of each student would be always immediately available, obviating any necessity for trips to wall lockers, either inside or outside the laboratory. Wall lockers for microscopes and student apparatus are unsatisfactory in that there is confusion and loss of time at the beginning and end of each laboratory period, incident to the securing of the equipment and its replacement. It sometimes happens, in addition, that frequent trips to the locker throughout the period, are unavoidable. These objections, while not important when dealing with small classes, become much more serious when a large class is handled in one room.

A second consideration was the desire so to design the desks and lockers, together with the trays, drawers and reagent boards used in connection with them, that all would be movable and freely interchangeable, thus permitting any grouping desired and the ready transfer of material and apparatus from storage to student lockers.

The furnishings have proved very satisfactory in use and have fulfilled in every way the conditions imposed. It was decided to use the Gage trays, as described in 'The Microscope', (10th edition, pp. 266-268), for the handling and storage of slides and sections. All locker specifications are, therefore, based on the size of these trays ($11\frac{3}{4}$ x $17\frac{1}{4}$ inches). The front elevation, section and plan of the laboratory desks are indicated on plate 1, the end on plate 2. It will be seen that each desk contains one microscope locker, two drawers and two reagent lockers. The upper drawer and reagent locker are reserved for the students of the first year class in histology and embryology, while the lower drawer and reagent locker are used by the second year class in the course in neurology. The microscope locker is used in common by both sets

of students. It will be noted that, while both reagent lockers are of the same size, the runways are differently placed. The first year students prepare a part of their material; the runways in the histology locker, therefore, are placed in the middle and carry a tray, shown on plate 2, arranged to handle all reagents used. In the space below are stored Gage trays, containing the assigned slides, loaned by the department, together with the preparations made by the student. In the course in neurology all slides are furnished by the department; in the lower reagent locker, therefore, the runways for Gage trays are placed at the top, leaving space below for pails containing human and sheep brains, together with a dissecting tray. The drawers are used for drawings, books, etc. Each desk is also equipped with a writing shelf on the right. A combination lock is used on the microscope locker, cylinder locks on the drawers and remaining lockers, each set possessing the same key, with a master key for all locks.

For instructors and other research men the desks shown in plate 2 are used. These are modified from desks designed by Professor Gage for the research laboratory in histology at Cornell. All locks on this desk are of the cylinder type.

For the private laboratories and preparation rooms for the storage of slides, apparatus, supplies, and general laboratory equipment, the lockers shown on plate 3 were designed, modified from those in use in Professor Gage's laboratory. These are so constructed that any number of sets may be placed side by side or a single case may be used alone. The lockers are equipped with drawers and reagent boards, taking also the Gage trays. Each locker is fitted with a cylinder lock and a spring thumb catch which may be used when the lock is not desired.

Probably most laboratory men using electric light for microscopic work have found difficulty in securing satisfactory portable stands. Those placed on the market by electrical supply houses, while fitted for general desk purposes, are too cumbersome for microscopic work and are usually not easy to adjust with reference to lighting the mirror. On the other hand, the portable stands furnished by the optical companies, such as the Spencer 375, are too expensive for use in large student laboratories. The lamp figured on plate 4 was designed, therefore, and has proved satisfactory. With the adjusting screws *B* and *C* working on the rods *D* and *E* any desired adjustment of the lamp may be secured. Fig. *A* shows the lamp as used in the student laboratory, fitted with a round green and opal glass shade and a round 16 cp. all frosted carbon filament bulb. Fig. *B* shows the same lamp, equipped with a half oval

shade, for general desk purposes. All the student desks are wired from floor plugs, with a socket on the rear, immediately below the top. Each desk is supplied with a lamp which is kept in the microscope locker unless needed, when the plug may be screwed into the socket in a moment. All switches are controlled from an instructor's room; in addition, each lamp may be conveniently turned on or off at the switch *A*.

The student laboratory at Pittsburgh contains fifty desks. In addition, there are sinks and tables fitted up for gas at either end of the room. Special reagents, stock solutions, etc., together with books, are kept in an instructor's room opening off the main laboratory.

Acknowledgments should be made to the H. J. Bool Company of Ithaca, and Mr. E. B. Lee of Pittsburgh, for their kindness in making the drawings of the desks and lockers, respectively; and to the E. Leitz Optical Company, whose electric microscopic lamp suggested the design adopted for the portable lamp illustrated.

EXPLANATION OF FIGURES

Plate 1. Front elevation, section and plan of the laboratory desk. The plan of this desk is identical with that of the research desk (plate 2).

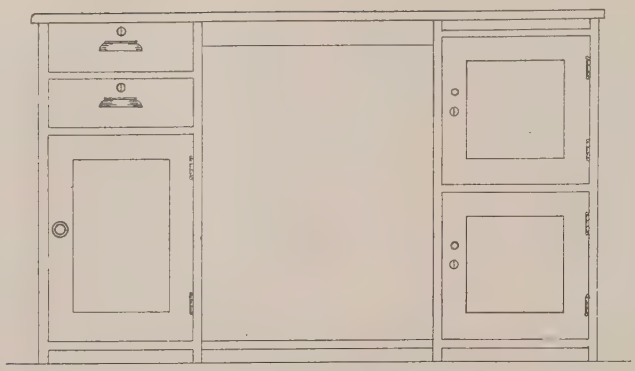
Plate 2. Front elevation, section and end of the desk used for research men. The end of this desk is identical with that of the student or laboratory desk. Shows also the reagent board or tray used in the student desk.

Plate 3. Shows front elevation, section, plan, end, etc., of the storage lockers, together with plan and section of drawers and reagent board. The reagent board holds fifteen staining jars, of the type used with the ordinary basket slide holders.

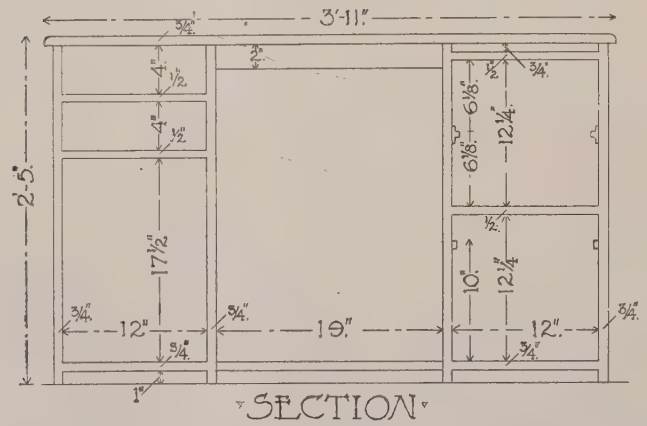
Plate 4. The portable electric lamp. $\times 1/3$. Fig. A shows the student or laboratory amp, fig. B the lamp when fitted w.th a half oval shade for general desk purposes.

SOME NEW LABORATORY FURNISHINGS

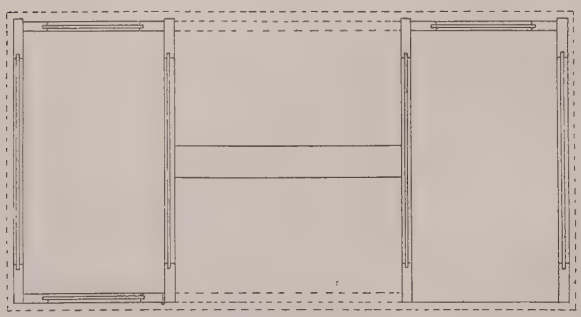
RALPH EDWARD SHELDON



FRONT ELEVATION

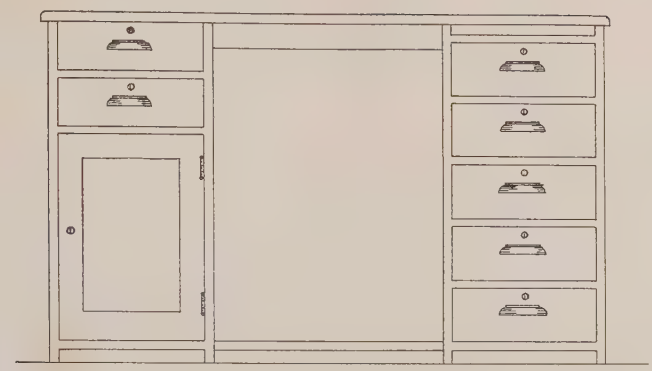


SECTION



PLAN

RALPH EDWARD SHELDON



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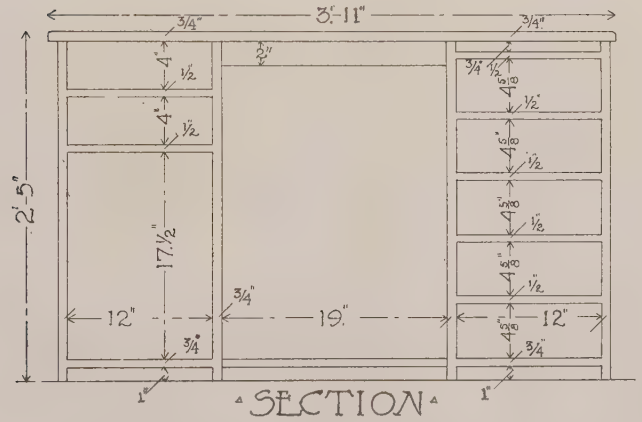
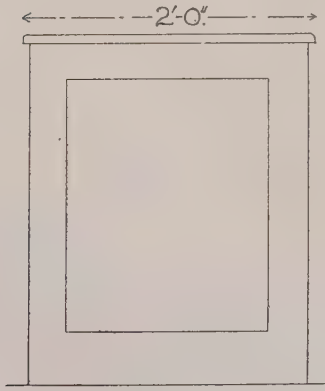
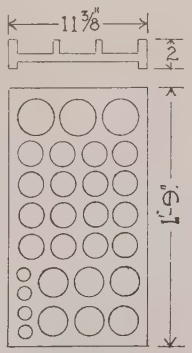


SECTION



END



TRAY

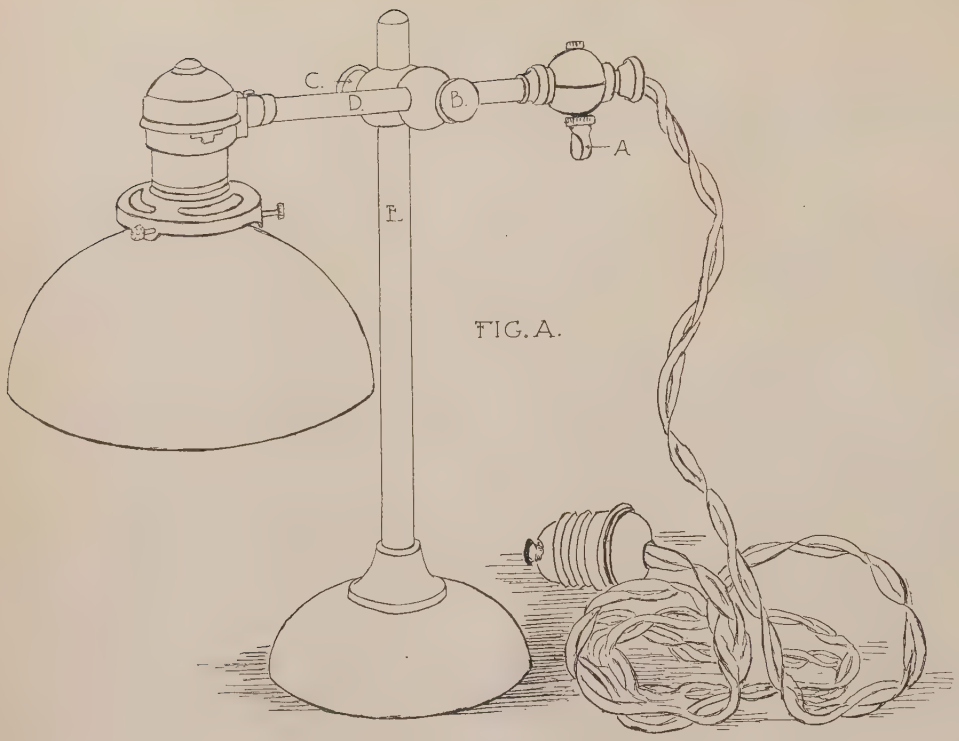


FIG. A.

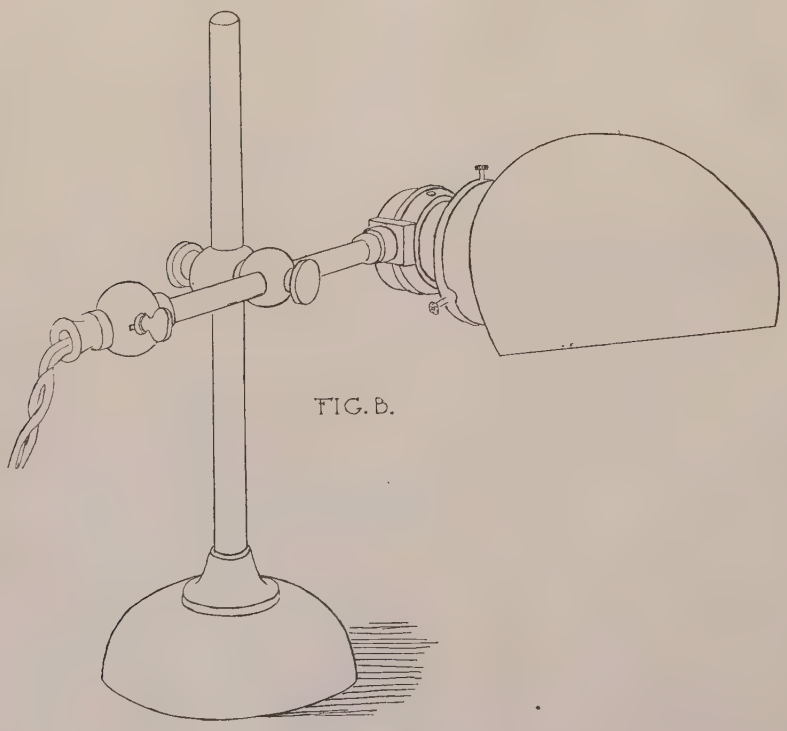
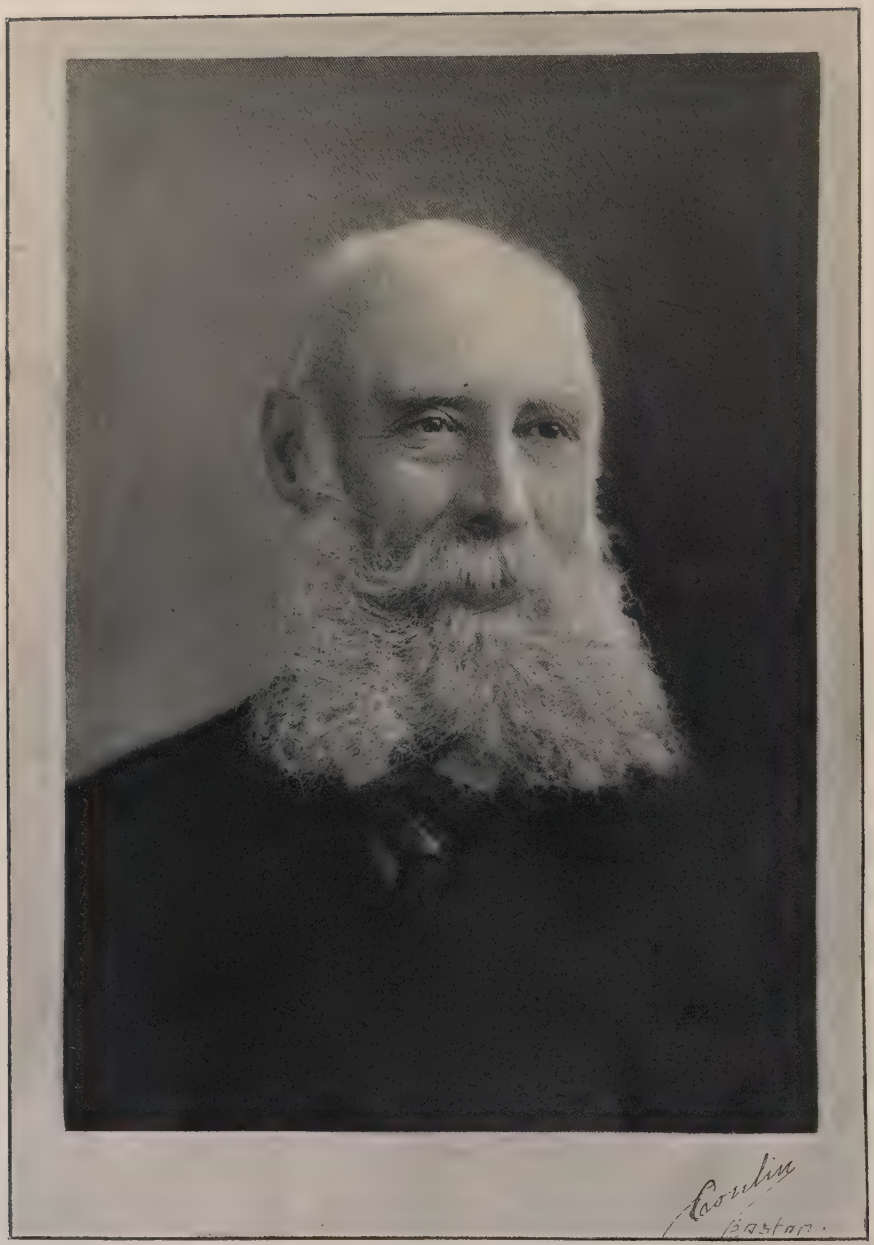


FIG. B.



THOMAS DWIGHT, M.D., LL.D.
1843–1911

THE ANAL GLANDS OF MEPHITUS MEPHITICA

M. W. BLACKMAN

From the Zoölogical Laboratory, Syracuse University

TEN FIGURES

The histology of the anal mucous membrane and its appendages has been the subject of a number of papers. These investigations, however, have been confined largely to domestic animals, very few wild animals having been studied in this way. This is especially noticeable of the carnivors where the anal region is remarkable for the presence of glands more highly developed than among other mammals in that here there is a certain kind specialized for the purpose of producing an odorous substance. In our common carnivors, such as dog and cat, the odor produced is comparatively mild and here probably serves a secondary sexual purpose. In other carnivors, however, the scent may be far from mild and in many cases is used either as a means of offence or defence. This is notably true of the Mustelidae, comprising the otter, badger, wolverine, mink, martin, ferret, ermine, weasel and skunk. In the last named animal not only does the secretion reach the perfection of nauseating fetidity but the mechanism of effectively directing its discharge has reached the highest degree of development. The animal is able not only to retain or discharge the secretion at will but also to eject it, for as great a distance as eight or ten feet and in any desired direction, thus having a very powerful weapon at its disposal.

So far as I have been able to discover the histology of the odoriparous glands of the skunk or similar animals has never been the subject of a careful study. The reason for this is perfectly obvious to anyone who has had even a distant or casual acquaintance with one of these animals. Indeed had the acquisition of the

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NOVEMBER, 1911

material upon which this paper is based depended entirely upon my own efforts it is probable it would never have appeared. The material was obtained by Mr. Fred Brown, a former student of histology with me, who is now professor of sciences in the University of Kiu Kiang, China. The material was fixed in Zenker's fluid, washed in water and run up through the grades of alcohol and was given to me at this stage of the process.

In obtaining the material no unpleasant results were experienced the animal being killed without discharging its secretions. The entire anal region including a portion of the rectum, the anus and its appendages and the vulva and a portion of the vagina was removed and placed in Zenker's fluid and later was cut into several pieces to allow more rapid and thorough fixation. The material was brought to the laboratory in the fixative and while a distinctly mephitic odor was apparent it was by no means unbearable, and soon disappeared. However, when the material reached the higher grades of alcohol and later when in the alcohol and ether the odor again became apparent. These reagents seemed to act as a solvent for the odorous substance and to aid in its rapid diffusion. In fact it was found advisable to devote a small well ventilated room entirely to the material, and for a week or more visits to this room were made as infrequent and brief as possible.

A portion of the material was embedded in paraffin, but the larger part of the anus and its appendages was embedded in celloiden. One celloiden block included an entire gland and its storage vesicle and a portion of the other one. Sections from this block proved the better for study as the larger size of the sections show the relations of the various parts more completely and the greater thickness at which they were cut contribute toward the same end.

The anal membrane of the dog has been studied by Hebrant[1] ('99), Zimmerman[2] ('04), Mladenowitsch[3] ('07) and others.

[1] Hebrant, G., 1899. Sur les glandes anales du chien. Ann. de Med. vet., vol. 48, pp. 633–641.

[2] Zimmerman, 1904, Untersuchungen des Analtegumentes des Hundes. Arch. f. wissensch. prakt. Tierheilk. Bd. 30, pp. 472–515. Taf. V–VI.

[3] Mladenowitsch, L., 1907. Vergleichende anatomische Untersuchungen über die Regio analis, und das Rectum der Haussängetiere. Inaug. Diss. Leipzig, pp. 1–152.

Mladenowitsch has made an especially detailed study of its macroscopic and microscopic anatomy and has found quite a number of different sorts of glands. These may be briefly summarized as follows: (1) The anal glands in the restricted sense of the term—large alveolar glands, lying in the zona columnaris, producing a fatty secretion and opening by ducts possessing decided enlargements which are occasionally visible macroscopically. (2) The circumanal glands, lying in the anal ring and differing from those of similar name in homo in being modified sebaceous glands instead of enlarged sweat glands. (3) In the walls of the anal sacs which lie laterally and ventrally, compound tubular glands of the general type of sweat glands, but producing a different kind of secretion. (4) In the walls of the outlets of the anal sacs slightly modified sebaceous glands.

With regard to the anal glands of Mephitus or similar animals the only reference I have been able to find is a very brief account accompanied by a figure by Dahlgren and Kepner[4] ('08). They describe the scent glands as follows: "In section these glands present but slight differences to the eye from the common sebaceous glands of the hair in other mammals. They are somewhat larger with larger cells and clearer cytoplasm, and are placed on special primary invaginations of the integument on each side of the anus. The saccular glands with simple secreting epithelium are placed in groups that surround the glands of the sebaceous type. They thus are collected into a single mass, the scent glands. The cells of the sebaceous glands produce an oil and produce it in the same way that the ordinary sebaceous glands produce it, as far as we can see. But the chemistry and physiology of the process must be different for the oil produced is not a simple lubricant, but has volatile constituents that cause a most powerful odor. The secretion of the saccular glands is watery and either acts merely as a carrier for the odorous oil or is itself a constituent part of the scent producing discharge." Comment will be made on this later.

[4] Dahlgren, U. and Kepner, W. A., 1908. Principles of animal histology, The Macmillan Company, New York.

The macroscopic anatomy of the scent glands is fairly well known. In the Riverside Natural History, vol. 5, p. 391, the following account is given: "Each gland is a secretory sac in a muscular tunic, and is furnished with a duct to convey the secretion to a little teat-like pipe near the verge of the anus. Contraction of the muscular investment compresses the sacs and spurts . . . the fluid in two jets. The action is really the same as that of a syringe with compressible bulb."

By referring to fig. 1 some idea of the general relations of the constrictor muscle, gland, anal vesicles and the papillae may be gained although the section is unfortunately nearly a true coronal section, whereas a radial section would be more intructive. However, the following points may be seen. The large masses of voluntary muscles surround the vesicles and extend around the gland and to a certain extent in between its lobules. Two vesicles are shown and a part of two glands appear in the section. One of the vesicles, the upper one in the drawing is cut well toward one side so that it appears small and the thickness of its wall appears greater than it really is because the wall is cut through diagonally. Only a segment of the wall of the other vesicle shows but as it is cut radially, an idea of its size and the true thickness of its wall can be more accurately observed.

The exit from each vesicle consists of a short thick tubule which extends posteriorly and mesially to open each side of the anus a little dorsal to the median horizontal line. Here the duct of the vesicle is continued into a distinct conical papilla. This papilla in my preparations lies in a sort of cavity or sheath like pit (fig. 1). It is probably true that ordinarily the papillae lie thus retracted in their sheaths and that they are only everted when the fetid secretion is discharged. From a careful study of the series of sections (every tenth section having been saved to form a series) it would seem that the muscle which forms a sheath about the glandular masses is continuous with that used in elevating the tail. Thus the act of elevating the tail would cause the two papillae to be everted and if done violently enough would constrict the gland and vesicle and cause the forcible discharge of the secretion.

MICROSCOPIC ANATOMY

The odoriparous glands. The location of these glands has already been mentioned. They form a dense mass surrounding the storage vesicle, between it and the surrounding muscle. At most points the muscle is entirely shut off from contact with the vesicle but occasional strands penetrate in between the various divisions of the gland. These may even abut directly upon the outer coat of the vesicle, and at such places the connective tissue sheath of the muscle fuses indistinguishably with that of the vesicle.

The glandular tissue does not form an even layer around the vesicle but there may be a considerable mass at some point while in other places it is much less abundant. The larger masses which occur on the side opposite the exit tube are surrounded by a fairly definite connective tissue sheath with a rather rich vascular supply. From this sheath sheets of connective tissue extend into the gland dividing it into lobules. These septa contain numerous blood vessels. In the angular areas between the lobules small amounts of adipose tissue are present.

The gland itself is of the compound, branched-tubular variety (fig. 3). It has no resemblance whatever to a sebaceous gland. Its structure does not show the high grade of differentiation found in such organs as the salivary glands, pancreas, etc., there being no such marked difference in the character of the epithelium of the ultimate branches and that of the intralobular ducts. In fact, these ducts seem to be merely the meeting points of a larger or smaller number of tubules and to act as ducts incidentally without any appreciable change in the character of their epithelial walls.

A section of one of the ultimate tubules is shown in fig. 5. The secreting cells are moderately high columnar epithelium, the basal ends of which rest upon a very distinct membrane propria. The cells shown are apparently in the stage of active secretion and two very distinct regions are evident in the protoplasm. The portion of the cell nearest the basement membrane takes the stain lightly, this being particularly evident in the preparations stained with haemalum followed by Congo red. The basal protoplasm is very distinctly reticulated. The meshes of the reticulum are elongated

and arranged with their long axes perpendicular to the membrane propria. This arrangement is sometimes so pronounced and the meshes so regular as to give the impression of an epithelium with the basal half of the cell striated. The protoplasm at the free ends of the cells is much denser in structure and has a decided affinity for the Congo red. No reticulum is to be seen here, the meshes apparently being filled with numerous fine granules which are stained a reddish orange.

Cells in other tubules or even some cells in the same tubule may present a different appearance than that described. Some of them, or even all, may be much smaller—both shorter and narrower—than those above mentioned (fig. 6). In these smaller cells the protoplasm also appears of a different structure. Short and relatively wide cells are common (fig. 6), in which the denser protoplasm fills nearly the entire cell leaving only a very thin basal margin of the clear reticular protoplasm. Others of the smaller cells, are relatively much narrower, and in these the greater portion of the cell is occupied by the reticular protoplasm. Here the meshes of the reticulum are very much elongated in the direction of the long axis of the cell.

Now as regards the explanation of the appearances described. It is believed that the large cells possessing the two distinct zones of protoplasm are cells at the height of secretion. The dense granular zone at the free end of the cells probably contains the more solid parts of the secretion—possibly the odoriferous portion. The lighter area of protoplasm probably represents the more liquid part—the fluid being contained in the enlarged meshes of the reticulum. The smaller cells are those from which the larger part of the secretion has been passed out. The short broad denser ones still contain a considerable quantity of the solid portion of the secretion, and only a small amount or none at all of the liquid secretion, while the small narrow cells contain either practically no secretion or only a small quantity of the fluid portion.

From the description it will be seen that the production of the secretion involves neither the destruction of entire cells as is known to occur in sebaceous glands, nor the breaking down of

the free ends of the cells as is said to occur in the mammary gland. The process of secretion here involves the production of intracellular materials which are elaborated within the protoplasm of the cell and which are later extruded and form the specific secretion.

The nuclei of the secreting cells are rather large, their diameter often filling nearly the entire width of the cell. They are usually approximately spherical in shape and contain a considerable amount of chromatin. Each nucleus contains a nucleolus-like body which from its staining reaction may well be chromatin. (However, I have used no stains other than haematoxylin and thionin to determine this point.) The remaining chromatin is granular and is arranged in flake like masses on the linin reticulum. A considerable number of cells contain nuclei which are not spherical, but of very irregular outline—polymorphic nuclei. Several such nuclei are shown in fig. 5. It has been suggested that these occur in cells which have been over active in secreting and that the polymorphic condition is the result of fatigue, but a careful study of my sections furnish no evidence supporting such a view. The extra nuclear cell-contents in these cells differs in no observable way from that in other cells containing spherical nuclei. The two zones of protoplasm are apparent, showing that active secretion is still going on. On the other hand there is no evidence tending to show that the appearance is due to an artifact.

Besides the secreting cells another type of epithelial cell is present in the tubules. These are small cells lying next to the membrana propria wedged in between the bases of the larger columnar cells. They are angular in shape and contain nuclei small in comparison with those of the secreting cells but large in proportion to the size of the cell and more rich in chromatin. In shape they vary from oval in the smaller cells to spherical in the larger ones. These cells are evidently 'replacing cells' which grow and take on the function of secretion when the secreting cells wear out.

The secreting cells of the tubules surround a definite lumen. In the ultimate tubule the lumen while large as compared with those many glands, does not form an expansion and as the cells are

higher here than in the ducts the gland conforms strictly to the tubular type. The secreting cells are not of uniform height and thus the lumen is quite irregular in shape. The free ends of the cells possess no cuticule. They are, however, surrounded by a quite definite membrane which apparently remains intact during all stages of secretion.

The lumina of practically all of the tubules in my sections contain a considerable amount of secretion, and this appears microscopically as a vacuolated or foam like mass of material which in unstained sections is of a distinct yellowish color. These vacuoles or globules are crowded together like droplets of oil in an emulsion. In stained sections some of the vacuoles contain rather coarse granules, while others are transparent and their contents structureless. Both coarse and fine granules surround the vacuoles while the interstices which are occupied by neither vacuoles nor granules probably contain a watery substance.

As I have previously stated there is little if any difference between the epithelium of the ultimate tubules and that of the intralobular ducts. Indeed, the similarity extends even to the presence of the protoplasm zones, showing that the cells lining the ducts are as actively secreting as are those of the tubules. In fig. 6 is shown a portion of the wall of one of the larger intralobular ducts. It will be seen that the epithelium here is essentially similar in all respects to that of a tubule shown in fig. 5. The relatively lesser height is due to a difference in the stage of secretion. The large globules of secretion, one lying in the lumen opposite each cell, have apparently just been extruded and are still transparent and non granular. They have not yet undergone the changes which are apparent in the globules toward the center of the lumen, which have been out of the cells longer. Appearances exactly similar may be seen in many of the ultimate branches.

The odoriparous gland is a comparatively small gland composed of a relatively small number of lobules so it would naturally follow that the duct system is not complicated. As the glandular layer surrounding the storage vesicle is rarely more than two lobules in thickness, the interlobular ducts are few and short. The epithe-

lium lining the ducts is similar in character but not identical with that of the intralobular and terminal tubules. The columnar cells are rather lower and usually show no evidence of being active in secretion, but occasionally they differ in no observable way except location from those lining the ducts inside the lobules. The epithelium of such ducts is actively secreting and the cells show the same protoplasm zones that are characteristic of that of the other regions of the tubule. Replacing cells are present here also.

The interlobular ducts pass toward the storage vesicle and penetrate its outer coats, but instead of each opening separately and directly into the vesicle, they converge toward one or several points in the wall of the vesicle and here empty into wide tubules. In the vesicle of which I have a series of sections, two of these pits are present. Each of them is an evagination of the inner coat of the vesicle and is lined by the same type of epithelium. This duct does not pass directly through the vesicle wall at right angles, but diagonally so that it appears in a large number of sections. Not only is the course diagonal, but where the duct opens into the vesicle, there is a flap of tissue, a prolongation of the inner wall of the duct, which when fluid is present in the anal vesicle, doubtless acts as a valve. It will be seen that the relation of parts here is very similar to that which is known to exist between the ureter and bladder, and the result accomplished is the same. Thus when pressure is brought to bear upon the contained fluid by the contraction of the surrounding muscles this flap is forced against the wall of the vesicle and prevents the return of the fluid to the ducts of the gland and the fluid is forced out through the proper channel.

The anal vesicle. The walls of the anal vesicle are rather thin but of a very firm consistency. The lining epithelium is of the stratified squamous variety possessing a distinct stratum corneum of considerable thickness. In some regions a stratum granulosum is plainly to be seen between stratum Malpighii and stratum corneum, while in other regions of the same section no such structure can be identified. The stratum corneum is much vacuolated and the side next to the lumen is much broken up. All of

the dead tissue presents a distinctly yellow stain and has the appearance of being partly macerated or corroded by the acrid secretion contained in the vesicle. The stratum Malpighii is comparatively thin, being only from four to eight cells in thickness. The basal cells rest upon a thin membrane propria plainly visible in some places and not apparent in others.

Beneath the epithelium lies the corium in which two layers are distinguishable. These correspond in position to the pars papillaris and pars reticularis of the skin, but not entirely so in structure. The upper layer while firm in structure is not so dense as the corresponding layer in the skin. It seems to be intermediate in structure—as would be expected from its origin—between the tunica propria of the rectum and the pars papillaris of the skin. The fibers—both white fibers and yellow elastic—are felted to form a dense meshwork, although not so dense as in the skin. The cells are more numerous and many lymphocytes are present, in some regions being so numerous as to warrant calling such aggregations diffuse lymphoid tissue. In my preparations I have found no true circumscribed lymph follicles in the vesicle wall, although these are numerous in the corresponding structure in the dog. The papillae are usually low and blunt and are not numerous and some regions are nearly devoid of them. In one of the vesicles (fig. 1), the inner layers of the wall are thrown up into folds or rugae, while the inner wall of the other vesicle of the same animal is comparatively smooth. This is correlated with a greater or less extension of the vesicle due to the presence of a greater or smaller amount of enclosed fluid.

The layer of the vesicle corresponding in position to the pars reticularis of the skin is of a much denser structure than the pars papillaris. It consists of a very firm and close felt work of fibrous tissue—nearly entirely white fibrous—surrounding a rich supply of very thick walled arteries and veins. Embedded in this dense meshwork are bands or even broad sheets of nonstriated muscle. This doubtless corresponds to the muscularis mucosae and is probably a derivative of this layer in the rectum—the entire anal vesicle being an evagination of the anal membrane in the region of transition between rectum and skin. The muscular constituent

of the outer wall of the anal vesicle is rather variable. In some regions it forms a considerable layer while in others it may be entirely absent or represented by only a few strands. Between the outermost layer of the anal vesicle and the surrounding gland is usually a greater or less quantity of loose areolar tissue well supplied with adipose cells. The adipose tissue fills in the angular areas between the various divisions of the gland where it may possibly serve as a sort of buffer. In places where no part of the gland intervenes between the constrictor muscle and the vesicle the epimysium of the former often fuses indistinguishably with the outer wall of the vesicle.

The constrictor muscle is of the voluntary striated variety. In general its arrangement is such that it surrounds both vesicle and gland but on the posterior mesial aspect in the region of the base of the excretory papilla little or no glandular tissue is present and here the muscle lies immediately outside the vesicle. The union is so close that it seems here to form an outer layer to the vesicle. The arrangement of the muscle, which is said to be a part of that which elevates the tail, is very irregular. At some places it forms a very thick layer while in others it is much thinner.

The excretory duct and anal papilla. The excretory duct of the vesicles arises from its posterior mesial aspect. It is short and thick, the greater portion of its bulk being voluntary muscular tissue. The inner layers are a direct continuation of those of the vesicle, the stratified squamous epithelium passing over unchanged. The corium is at first similar to the papillary portion of the same layer in the vesicle. At a little distance from the base, however, a change is evident. The tissue becomes looser, the fibers are less densely felted and the papillae more numerous and higher. The outer fibrous coat is not present in the excretory duct, the next layer in order being a very thick layer of voluntary muscular tissue, which occurs in the form of numerous bundles of various sizes (figs. 1, 8). The general arrangement of these is in a circular direction, but some extend longitudinally. That this layer of muscle bundles is a continuation of the constrictor muscle of the vesicle is evident from a study of fig. 8, which represens a section of the excretory duct just at the point where it reached the sur-

face of the anal membrane. The continuity of a strand of the constrictor muscle and the muscular layer of the duct is plainly seen.

The function of the muscular layer of the duct is apparent. It consists largely of circular fibers which act as a sphincter and thus retains the secretion until the animal desires to void it. The longitudinal bundles of muscle which are much more numerous toward the end of the excretory papilla are of use in directing or 'aiming' the papilla.

The next layer in the wall of the duct outside the muscular stratum is made up of connective tissue. In the basal region this is quite loose meshed and merely serves to unite the duct with the surrounding parts—muscles or glands. Nearer the free end of the duct where it lies in the anal papilla, the outermost layers are those of the anal mucous membrane—namely a stratified squamous epithelium overlying a fairly firm connective tissue corium. The epithelial layer differs from that of the vesicle and its duct in having no true stratum corneum. The stratum Malpighii is also of considerably greater thickness. The corium is peculiar in that it is entirely devoid of papillae.

The anal membrane in the region of the anal papillae is covered by the same type of epithelium as that on the outside of the papillae. It possesses no stratum corneum but gradually acquires this as it passes over into the skin surrounding the anus. The underlying connective tissue also gradually changes from the comparatively loose corium of the anal membrane to the denser dermis of the skin.

Other anal glands. Besides the true odoriparous anal glands described above several other kinds of anal glands occur in the skunk. At the base of the anal papilla and in the adjacent anal membrane occur groups of modified sweat glands. Several of these glands are shown in among the muscles surrounding the base of the anal duct in fig. 8. Other groups are shown at a greater magnification in fig. 9. A study of these drawings will, I think, convince one beyond a doubt that these are modified, branched, sweat glands. These glands lie deep in the corium or even deeper in among the bundles of muscles. Under very low

magnification they look but little different from ordinary sweat glands except in the size of the groups and the diameter of the constituent tubules. With higher magnification, however, it is plainly seen that the tubules are branched. Possibly the best evidence for their being called modified sweat glands is furnished by the character of the ducts. In fig. 9 two sections of the duct are shown—one where it connects with the valley surrounding the base of the papilla, and the other lying deeper in the connective tissue. In both the epithelium in the wall is in the form of a double layer of cells similar to that of an ordinary sweat gland.

An interesting point regarding these glands is their very apparent similarity on the one hand to sweat glands and on the other hand to the true odoriparous glands. They may be said to form a connecting link between the unbranched, coiled, sweat glands and the very much branched odor producing glands. In preparations of the anal structures of the dog which I made for purposes of comparison (also compare Mladenowitsch, loc. cit.), the glands surrounding the anal sacs are strikingly like the modified sudoriparous glands in the skunk at the base of the papillae. It is very probable that phylogenetically the glands of the anal sac in the dog and the odor producing structures of the skunk are homologous. This then would seem to justify the conclusion that the odoriparous glands in Mephitus are much modified and enlarged sweat glands.

In addition to the two sorts of glands described true circumanal glands similar to those in the dog are also present. These are very much enlarged sebaceous glands which surround the anus just outside the anal ring (fig. 1). They are primarily superficial in position, but are often so numerous, that some of them are crowded down into the deeper layers of the corium and may even be forced in among the bundles of muscle. In essentials of structure these glands are like the typical sebaceous glands except that they are much larger and more branched (fig. 10). The ducts do not connect with hair follicles, there being none present in this region, but empty into deep wide pits (figs. 1, 10), which extend down from the surface of the anal membrane. These pits are lined with stratified squamous epithelium which as with the

membrane in this region possesses a distinct, thick, cornified layer. The squamous epithelium including a stratum corneum extends down to form the lining of the various branches of the duct even to those connecting directly with the acini.

From the foregoing description it is evident that Dahlgren and Kepner (loc. cit.), who give the only account of the microscopic anatomy of the anal glands of Mephitus which I have been able to find, are mistaken in believing the sebaceous glands to be those concerned in the production of the odoriferous secretion peculiar to this animal. They mention two sorts of glands as being concerned in the production of the odorous fluid. One of those, the one which they consider most directly concerned, is the circumanal gland of the sebaceous type. They also mention certain saccular glands which from their position must correspond to the modified, branched—tubular sweat glands which lie in the same general region as the circumanal glands. It would seem that in obtaining their material they removed only a portion of the anal membrane and thus obtained none of the true odoriparous gland.

Syracuse University,
June 1, 1911.

LIST OF ABBREVIATIONS USED ON THE PLATES

adip. tis., adipose tissue
an. surf., anal surface
bl. ves., blood vessel
circ. an. gl., circumanal gland
circ. musc., circular muscle
intralob. d., intralobular duct
interlob. d., interlobular duct
invol. musc., involuntary muscle
mod. sudor. gl., modified sudoriparous gland
musc., muscle (voluntary)
odor. gl., odoriparous gland
papil., papilla
repl. c., replacing cell
secr. tub., secreting tubule
val., valve
ves., vesicle

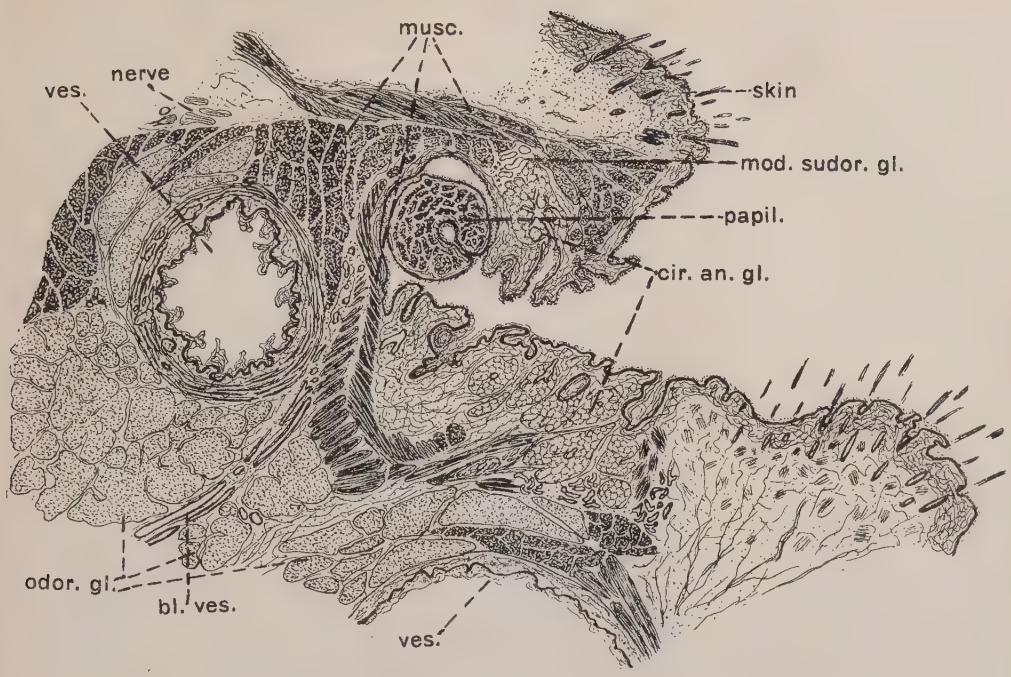
PLATE 1

EXPLANATION OF FIGURES

All drawings were made with the aid of a camera lucida. All have been reduced one-fourth in reproducing.

1 Coronal section of the anal membrane and adjacent structures in Mephitus mephitica, showing the three sorts of modified integumentary glands—also the apparatus for the storing and ejection of the odoriferous secretion. The meanings of the abbreviations used in indexing figures are given on a preceding page. × 5.

2 Segment of the vesicle wall and the adjacent odoriparous gland on the side opposite the excretory duct. Showing the division of the gland into lobules and the position and relative sizes of the various ducts. × 15.


musc.
nerve
ves.
skin
mod. sudor. gl.
papil.
cir. an. gl.
odor. gl.
bl. ves.
ves.

1

invol. musc.
ves.
interlob. d.
intralob. d.
lobule

2

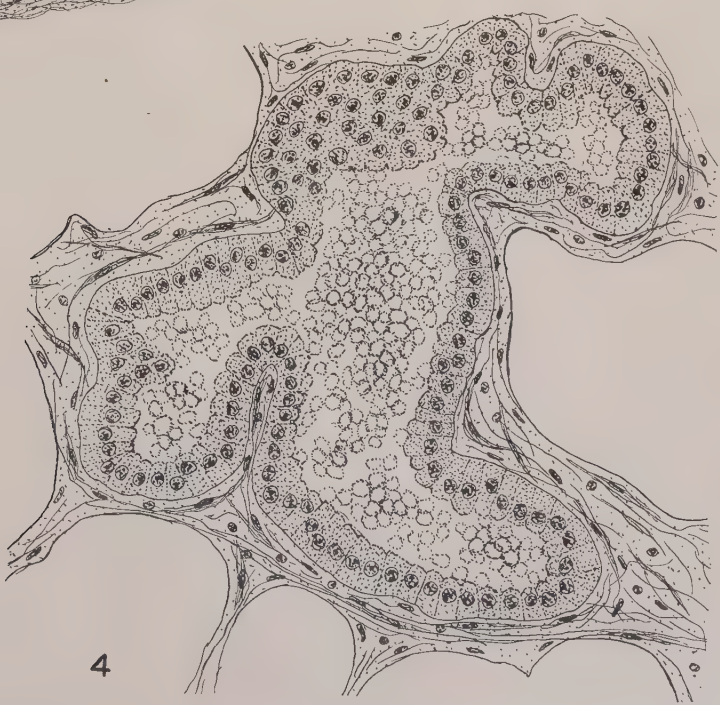
PLATE 2

EXPLANATION OF FIGURES

3 A portion of a lobule more highly magnified showing the mode of branching of the intralobular ducts and their relation to the secreting tubules. It will be noted that the lumen of the duct is much more expanded than that of the tubule. The lumina of both duct and tubule are filled with scretion. × 75.

4 Section of the point of joining of tubule and duct. The abundant secretion filling the lumen is very evident. × 275.

3



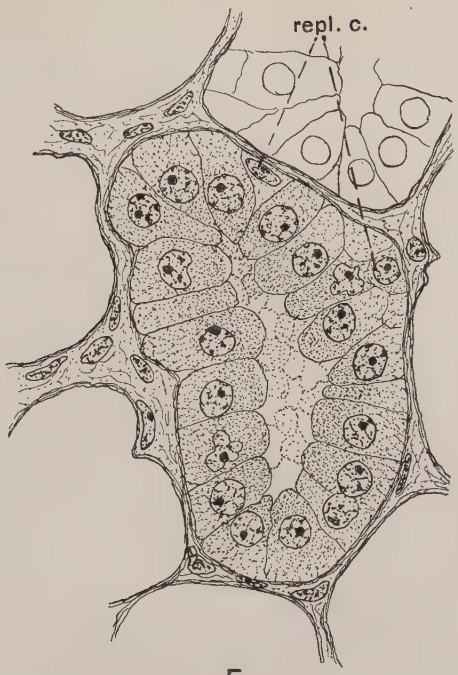
4

PLATE 3

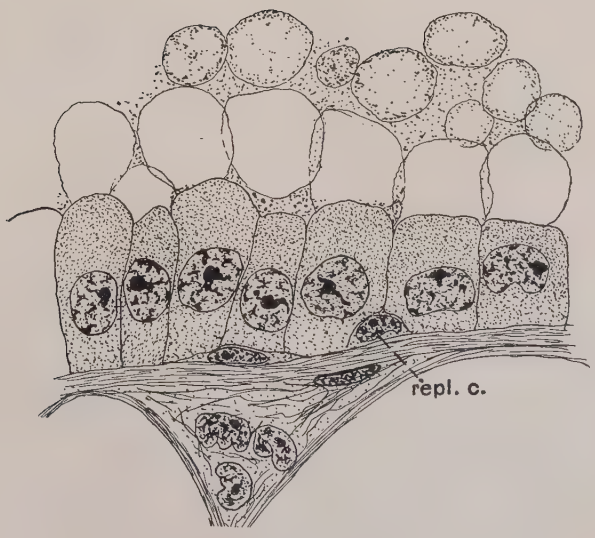
EXPLANATION OF FIGURES

5 Section of a secreting tubule showing the appearance of the cells during active secretion. The two zones of cytoplasm are evident. × 675.

6 Section of the wall of an intralobular duct, showing cells actively secreting. Some of the secretion, apparently just extruded from the cells, is seen in the lumen (above in drawing). × 1125.



5



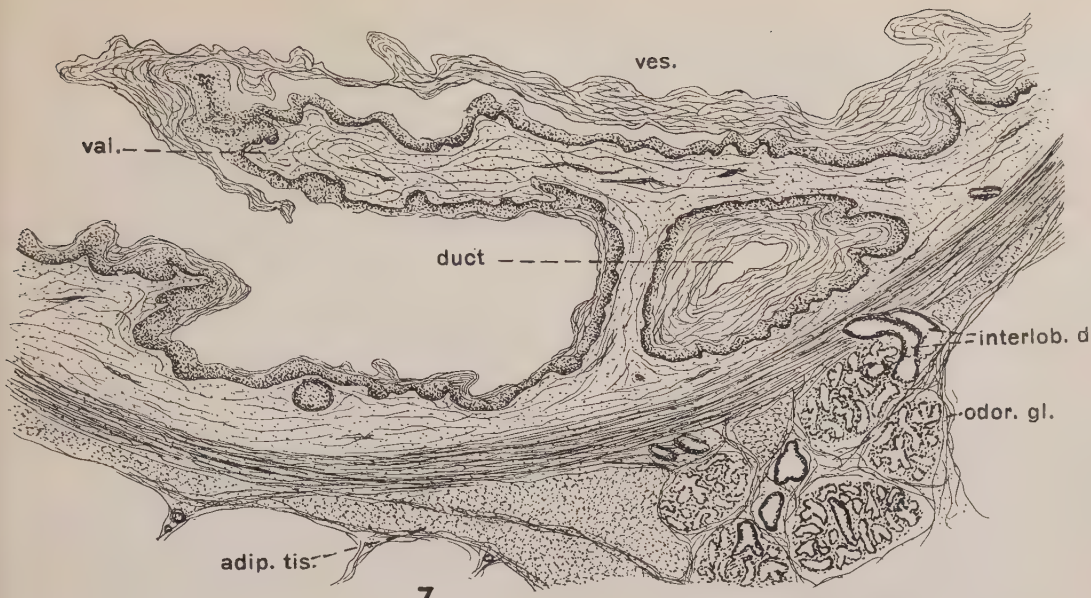
6

PLATE 4

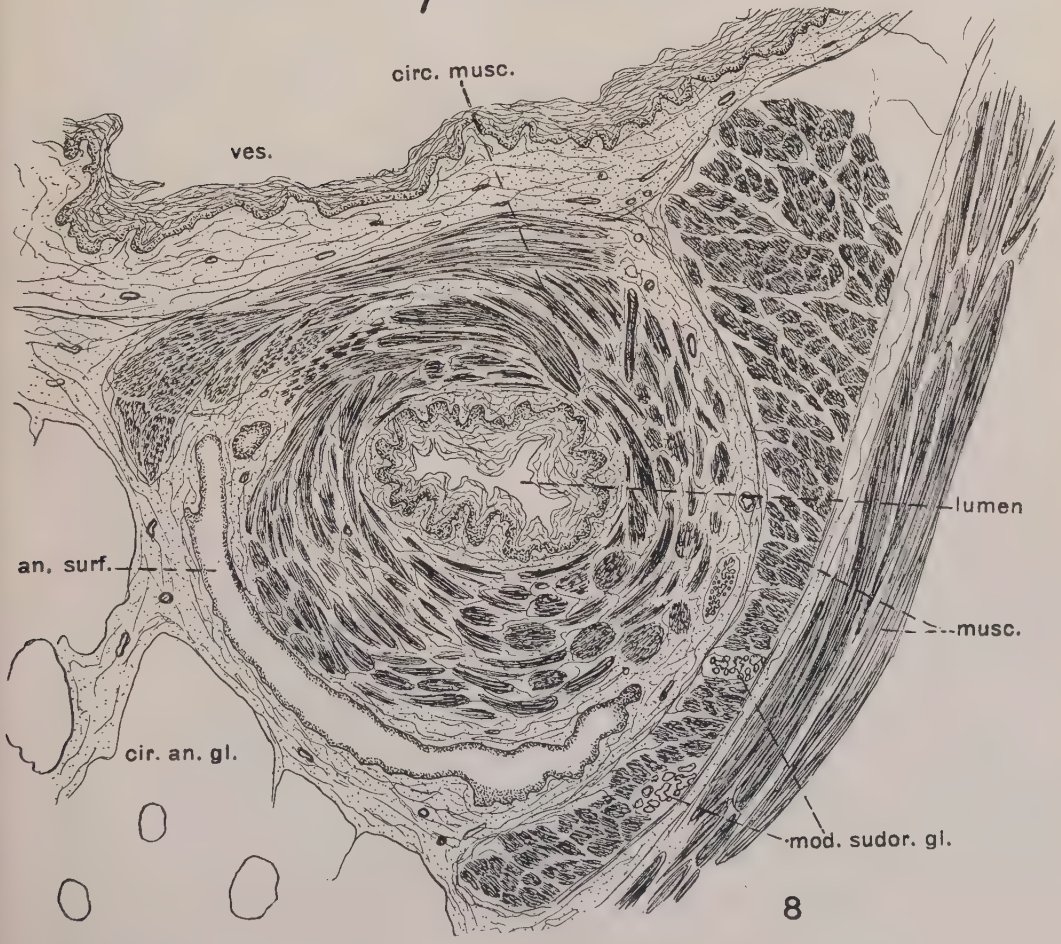
EXPLANATION OF FIGURES

7 Section through the wall of the vesicle showing cross section of the main duct of the gland near point of entrance and section of the flap of tissue which acts as a valve. × 25.

8 Section through wall of vesicle and through its excretory duct just at the point where it passes into the papilla. The continuity of the constrictor muscle of the vesicle and the circular muscle of the papilla is shown. × 20.


ves.
val.
duct
interlob. d
odor. gl.
adip. tis.

7


circ. musc.
ves.
lumen
an. surf.
musc.
cir. an. gl.
mod. sudor. gl.

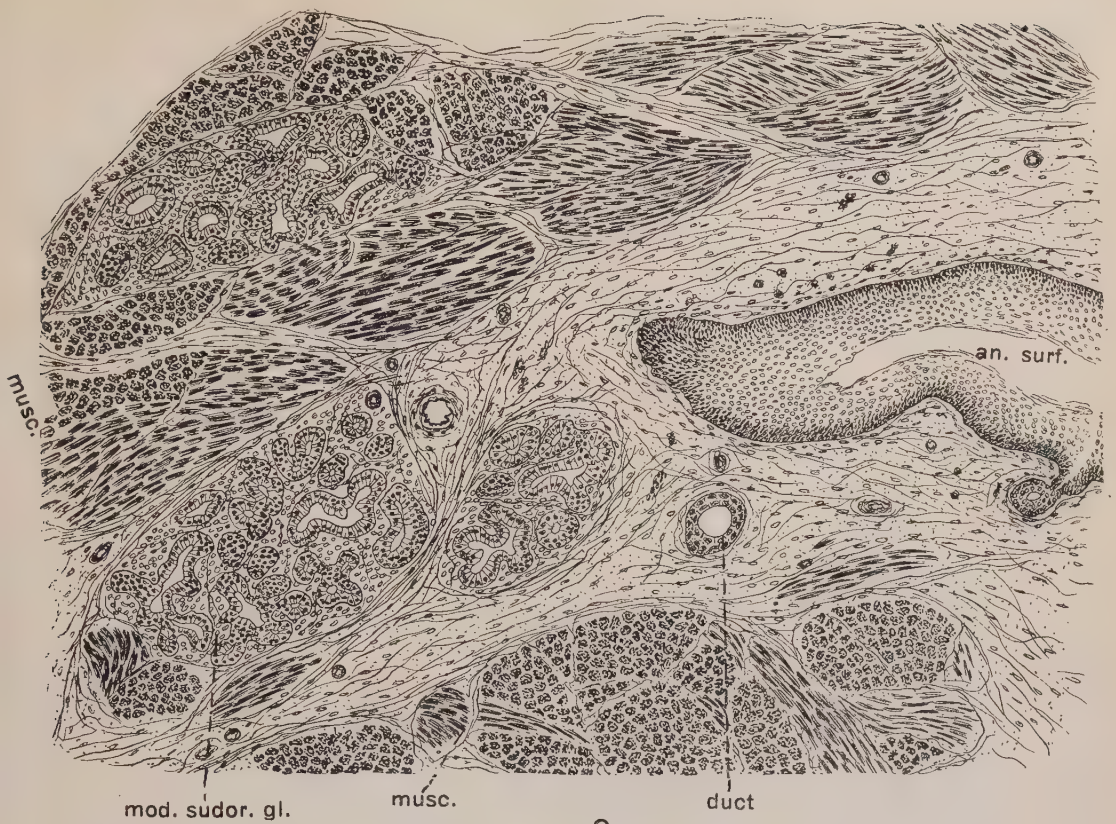
8

PLATE 5

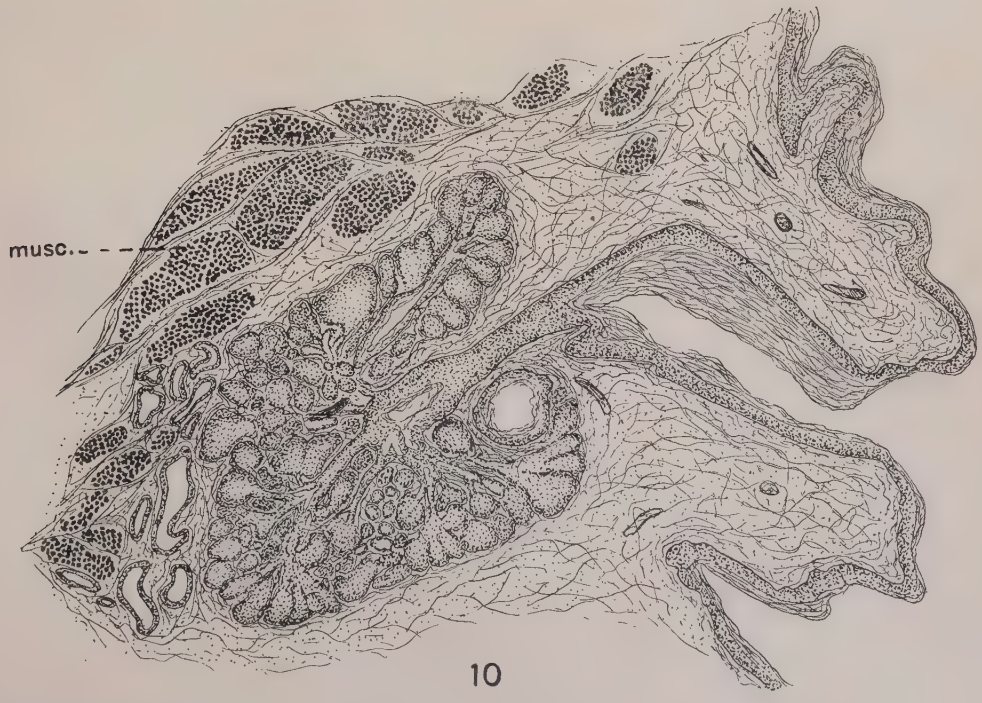
EXPLANATION OF FIGURES

9 Through region of base of papillae (circular muscle of papilla shown in lower part of figure), showing the modified branched sudoriparous glands and their ducts. The duct to the right is sectioned just at the point where it empties upon the anal surface in the valley at the base of the papilla. × 75.

10 More highly magnified view of one of the circumanal glands shown in fig. 1. This type of gland has been erroneously described as that concerned in the production of the odor of Mephitus. × 25.



9



10

THE STRUCTURE OF HEART MUSCLE OF THE HUMMING BIRD, WITH SPECIAL REFERENCE TO THE INTERCALATED DISCS

H. E. JORDAN

From the Anatomical Laboratory of the University of Virginia

FIFTEEN FIGURES

INTRODUCTORY AND HISTORICAL

Notwithstanding a great amount of careful microscopic work on mammalian cardiac muscle, it still remains an open question whether in the adult condition it is syncytial or cellular. The opposing views are equally cogently urged by such authorities, as, for example, Heidenhain and Zimmermann. The designation of cardiac muscle as a tissue or as a syncytium depends upon the interpretation given to the so-called intercalated discs or junctional lines (also, bands of Eberth[1]), i.e., whether or not they mark cell boundaries.

Though the question of structure of mammalian heart muscle is not now regarded as important as formerly from the standpoint of heart physiology, it has lost none of its early interest from the standpoint of pure histology nor from that of the physiology of contractility. Since the discovery and more thorough study of the sino-ventricular bundle of His, which is now believed to be syncytial and to contain neurones, the syncytial or cellular structure of the heart musculature is no longer urged in favor of the myogenic or neurogenic theory of heart beat respectively. Moreover, the now well established fact that the myofibrillae pass uninterruptedly through the discs (Heidenhain), whether they are cell boundaries or otherwise—on the assumption that the fibrillae

[1] These are the "Schaltstücke" of Heidenhain; the "Kittscheiben" or "linien" or "streifen" of v. Ebner; and the "bandes tranversales" of Marceau.

are the essential conducting elements of the wave of contraction—has likewise robbed the discussion of its earlier significance. Nevertheless, in view of the doubtful nature and function of these structures it seems desirable that additional evidence, gathered from a broader field of material, should continue to be presented.

Since intercalated discs are said to appear first in heart muscle of birds, it seemed that here they might possibly be found in their simplest form and under conditions more readily disclosing their real nature. Believing, on purely *a priori* grounds, that in the humming bird, with its generally delicate and highly sensitive organization, the heart muscle would furnish a favorable material for a study of these discs, this form was chosen for this investigation. The results, at least in the matter of the microscopic pictures, have, I believe, demonstrated the correctness of this surmise. The study is purely a histologic one; and the main end sought is to prove that the intercalated discs are *not* cell boundaries or cement lines.

It seems well at the outset to call attention to these several facts: (1) Intercalated discs, as above stated, have not been found in the animal kingdom below birds; (2) they do not appear in man and many mammals (e.g. sheep) until after birth; (3) in the earlier stages of development avian and mammalian heart musculature is syncytial; (4) the discs are apparently more numerous in mammals than in birds[2]; (5) the discs are not equally abundant throughout all portions of the same heart. From the viewpoint of phylogeny these several facts indicate that, in respect to the absence of these discs, avian and mammalian embryonic stages recapitulate ancestral reptilian adult stages. From the standpoint of physiology the presence of these discs would seem due to an additional function, or greater degree of functional activity, of higher vertebrates and adult avian and mammalian forms.

The older view (Eberth, '66; Schweigger—Seidel, '71) regarded these discs as intercellular structures, marking cell boundaries. They were variously interpreted as cement lines or protoplasmic

[2] They are also said to be more numerous in dog than in man or sheep (Marceau); and more numerous in the latter than in cat and rabbit (Moriya).

bridges. The observations in support of this interpretation were: (1) tendency of heart muscle to rupture along the course of these discs—Eberth and others; (2) typical reaction to silver nitrate treatment for demonstrating cell outlines—Eberth and others; (3) presence of ground-membrane on either side apparently continuous with sarcolemma, leaving the discs intercellular—but not of the usual nature of intercellular substances, according to Heidenhain.

The more recent view dates from the work of Przewoski ('93). This view received further support by the able work of von Ebner ('00); and has been most successfully urged by Heidenhain ('01) and Marceau ('02). It regards cardiac muscle as a syncytium, recognizing no evidence at any stage of distinct or separate cells. The cell areas are regarded as continuous laterally and longitudinally. Observations in support of this position are: (1) syncytial character of developing heart muscle (certain mammals, v. Ebner, '00; pig, McCallum '97); (2) in many vertebrates (i.e., below birds) no cell territories have been made out in the myocardium; (3) the discs extend only part of the way across a fiber; (4) they mark off irregular spaces; (5) some of the latter contain more than one nucleus; (6) others are non-nucleated; (7) the contractile fibrils pass through the junctional lines without interruption. It may be remarked that points 5 and 6 do not really seem to be serious objections to the earlier alternative view.

Various interpretations have been given to these discs by the supporters of the recent view: (1) that they are contraction zones—von Ebner; (2) that they are supports[3] for the myofibrillae on which that may, perhaps, pull in contracting—Marceau; (3) that they are places where fibrils may grow to form new segments, thus comparable to unbanded embryonic fibrils—Heidenhain; (4) that they mark the boundaries of specific physiological conditions —Spuler; (5) that they are contraction artefacts of rigor mortis —J. Schaffer.

Recently Palczewska ('10) made a careful study of human heart musculature and concludes that the earlier view of Eberth and

[3] i. e., tendon-like structures, 'pièces de perfectionnement'.

Schweigger-Seidel is correct. This paper contains a very excellent review of the literature on this subject, to which the reader is referred for further historical information.

Werner ('10), after a study of the heart musculature of a number of mammals, including pig, calf, sheep, rabbit, rat, cat and hedgehog, comes to the same conclusion; namely, that heart muscle is a tissue composed of distinct cells, the boundaries of which are marked by the intercalated discs.

E. A. Schäffer ('10) also has recently expressed his opinion that heart muscle is "first a syncytium within which contractile fibrils are developed, and only in mammals is a differentiation of the syncytium into cells produced; the lines of junction being even here bridged across by muscle fibrils." It must be observed, though, that these discs are not limited to mammalian heart muscle but are found also in that of birds.

v. Ebner argues that if the discs were cement lines they would interfere with contraction; the inter-disc segments would become barrel-shaped during contraction, which is not the case.

Marceau regards untenable Heidenhain's interpretation of the discs as growth zones, since in the sheep's heart the discs are absent until after its period of most rapid growth. Nor does he regard them as bounded by Krause's membrane.

The fact that heart muscle tends to break up along the site of the discs in certain mascerating fluids does not necessarily demonstrate that they are cell boundaries. In mascerating solutions striped muscle separates along Krause's ground and Heidenhain's intermediate membranes. The structural relationship of the intercalated discs with respect to these membranes, more particularly the latter, determines rupture along their site. Similarly with respect to their reaction to silver nitrate—this may simply mean that other structures or substances besides cement lines may take the silver stain.

Palczewska and also Werner used the technic recommended by Zimmermann, in whose laboratory the work was mainly done. This technic consists of fixation in a mixture of 10 parts of 25 per cent pure nitric acid and 90 parts of absolute alcohol; washing in 94 per cent alcohol until the reaction is neutral to litmus paper;

passing into distilled water, and then passing through the ordinary steps of the paraffin technic. I have employed the same technic with most excellent results. Sections were cut both transversely and longitudinally, at from 2 to 10 microns and studied by aid of a Leitz $\frac{1}{16}$ lens and various oculars, including a no. 18.

Palczewska gives a number of diagrams (figs. 1, 2, 9 and 10) illustrating the possible cellular structure of heart muscle. In terms of various sections of these diagrams she seeks to interpret the great variety of form and manner of distribution of the intercalated discs. The muscle cell is conceived of as a very irregular body with short branches,—the discs marking the limits of the cell and its processes. Discs shorter than the width of a fiber, step-like discs and non-nucleated segments are successfully interpreted in terms of sections through these diagrams. The diagrams and the discussion are quite convincing, until one looks at actual preparations. It might be urged that we know nowhere cells analagous to the two combined in fig. 9; and I believe Palczewska herself would have considerable trouble to interpret her figure 18 in terms of a cell boundary.

Both Palczewska and Werner describe and figure a membrane which they regard as equivalent to the sarcolemma of voluntary muscle. Heidenhain likewise recognizes such a membrane. With this interpretation, my findings in the case of the heart muscle of the humming bird are in accord. There is here a distinct membrane as I shall describe below.

With the conclusion which regards the discs as the cell boundaries I cannot agree for reasons which will appear in the descriptive part of this paper. I can add little definite to the discussion regarding the significance of these discs. The evidence, as will appear below, indicates, I believe, that their nature is similar to that of the anisotropic materials and that a solution of the structure and function of the one involves at least to some extent that of the other. The evidence, I believe, supports the position of a syncytial nature of the heart muscle even where intercalated discs appear.

DESCRIPTIVE

Disregarding for the moment the intercalated discs, the heart musculature of the humming bird is syncytial in character, the fibers anastomosing laterally and apically. The resulting structure is a close-meshed trabecular muscle network. Characteristic Purkinje fibers line the cavities of the heart. In transverse section the individual fibers are polygonal, circular or oblong in outline. The nucleus is centrally or sub-centrally placed (fig. 15). The fibrillae are collected into larger and smaller bundles, Kölliker's columns. Otherwise, the fibrillae are evenly distributed throughout the fiber, and leave free only a very small sarcoplasmic area about the nucleus. The fiber in transverse section frequently shows a sharply outlined peripheral sheath or membrane the equivalent of a sarcolemma (fig. 15). This membrane is occasionally very distinctly seen in longitudinal sections, when it has become lifted off from the fiber (fig. 8).

Passing now to the intercalated discs the following points may be noted: (1) They usually appear in patches, or in areas transverse to the long axis of the fibers (figs. 1 and 4); an arrangement permitting equally well of either of two interpretations— (*a*) cell boundaries; (*b*) local areas of special physiologic or functional state, perhaps a particular phase of a contraction wave. (2) They appear more numerous in curled contracted fibers or fibers under strain (figs. 2, 3 and 4); indicating that they may be casually related to contraction or stress, perhaps rigor mortis. (3) Likewise they are more abundant at the curled, rounded or pointed ends of fibers. (4) They occasionally lie over the nucleus (figs. 6 and 15); a condition contradicting an interpretation in terms of a cell boundary. (5) They are frequently at the same level and apparently continuous in adjacent fibers (fig. 2); an arrangement suggesting a like functional state in the two fibers rather than a continuous cement line. (6) They are always at the level, and frequently take the place, of the anisotropic band; where the disc extends across only a portion of the fiber it can frequently be seen to shade gradually into the anisotropic substance (figs. 1 to 4). (7) At a much contracted region of a fiber the discs are coarser;

and there is a gradual shading off in both directions from an undoubted disc, through coarse anisotropic bands to the usual condition (figs. 4 and 5). The intermediate anisotropic bands of the contracted area are apparently identical with discs in relaxed areas and would undoubtedly be so interpreted. (8) The discs are superficial, i.e., they are not complete or partial plates but merely narrow bands. This point can be confirmed by carefully focussing on the discs when it is seen that they always disappear from the field before the fiber disappears; *and by viewing them in transverse sections of the fibers, when they appear as merely thickened granular portions of the surrounding membrane* (fig. 15). (9) In contracted regions the anisotropic segments become wider; and the isotropic segments are narrower than in the non-contracted regions (figs. 4 and 5). Furthermore, frequently 2 or 3 discs lie at successive anisotropic levels and in these cases the intervening isotropic segments are also much narrower (figs. 7 and 9) than between two ordinary anisotropic segments. This observation indicates a relationship between contraction and the presence of discs, and a close similarity between the latter and the anisotropic substance of striped muscle. (10) The discs have no orderly arrangement with respect to the nuclei (figs. 1 and 2). (11) Frequently, where two discs immediately follow each other, one is at a higher level than the other. The one passes out of the level of focus as the second passes in. This might be interpreted as a tangential section through a region where the cement line is in the form of steps. But in that event, in passing from the one to the other through the two levels of focus, we should pass through the cement substance of the 'risers'—a darker zone, similar to the discs—which does not appear, the section accordingly being an oblique longitudinal one (fig. 7). (12) In instances where the disc is in the form of a succession of steps, the substance of the step frequently shades gradually into the anisotropic substance on both sides beyond the 'riser'; in other words the 'steps' extend beyond the limits of the 'risers' which would not be the case in respect to cement lines (fig. 10). (13) The discs vary considerably in coarseness; differing in this respect from the usual

character of cement lines (fig. 1). (14) Breaks produced in sectioning may occur anywhere, but only very rarely along the discs.

DISCUSSION AND CONCLUSION

The above-stated 14 observations demonstrate, I believe, that the intercalated discs of humming bird heart muscle are not cell boundaries or cement lines. The cardiac muscle of this form appears truly syncytial. Concerning the nature or significance of the discs there remains much uncertainty. Regarding their structure I can make no more definite statement than that they are finely granular; and very like that of the anisotropic segments. Many of these discs are mere dots rather than plates (figs. 13 and 14); this is frequently well shown where two fibers lie closely adjacent (fig. 11). I believe that the discs must be interpreted finally in terms of the ultimate fibrillae—not of the whole fiber. This cue was obtained from tissue fixed in Flemming's fluid and stained in iron-haemotoxylin. Here the fiber frequently appears broken up into fibrillae; on which the anisotropic bands vary from mere lines to very wide segments (fig. 12). Moreover these fibrillae are usually the peripheral ones (figs. 13 and 14); their location with respect to the fiber corresponding with that of the position of the intercalated discs.

The conclusion that these findings lead to, are that the dot-like intercalated discs are coarser anisotropic bands of the fibrillae; discs extending wholly or partially across a fiber represent rows of such bands of a larger or smaller number of fibrillae. Their linear arrangement indicates similar physiologic or functional conditions of that particular region. Their greater abundance in contracted fibers indicate a relationship to contraction. Their usually peripheral arrangement indicates causal relationship to an external agent. In fixed tissues this may perhaps be the fixing reagent. This surmise receives plausibility from the fact that they appear abundantly in Zimmermann's fluid (alcohol plus HNO_3—a violent fixing fluid) and only very sparsely and then very indistinctly and imperfectly in tissue fixed with Flemming's fluid (a weak fixative). The fact that they appear in patches and transverse areas, and in varying abundance in different parts

of the heart, indicates that they may represent a fixed phase of the contraction wave (i.e., of the final beat). And the further fact that microscopically and structurally there is an apparent identity between these discs and the anisotropic substance indicates that they represent at least only different conditions of the same substance. I must add here that in the heart muscle of the humming bird the discs are not bounded by the ground membrane of Krause, as described by Heidenhain for certain mammals, but they seem to displace the anisotropic or Q band.

Finally, the fact that these discs have not been found in the hearts of lower vertebrates nor during foetal stages[4] indicate that they are somehow associated with an advanced stage of development or a higher degree of function—*or are perhaps the result of function.* If the last idea were true, we should expect to find them more abundantly in old than in young individuals, a point which as far as is known to me has not yet been tested. When we consider simply the comparative histology of skeletal and cardiac muscle, it might be concluded that the presence of the discs is associated with rhythmic contraction; but this opinion is invalidated by the fact that they are absent in the foetal heart. That the discs are somehow associated, however, with contraction is indicated by their generally peripheral location, greater distinctness and abundance in tissue killed with strong reagents, and their greater abundance in contracted fibers.

In the heart of the humming bird, then, the microscopic evidence respecting the intercalated discs renders impossible their interpretation as cell boundaries or cement lines. They are structurally and tinctorially apparently of the same nature as the anisotropic bands, are closely related to them in position, and most probably represent a definite physiologic or functional state—or perhaps are the effect of function.

[4] I am now able to report intercalated discs—but in comparatively smaller numbers and simpler condition than in certain mammals, e.g., guinea pig and monkey—in a reptile (turtle), amphibia (frog and toad) and a teleost fish (trout). Moreover, in the guinea pig, discs appear during the last week of gestation. These findings, which will form the basis of a separate paper, do not, however, controvert the above conclusions, as I shall attempt to make clear in a later discussion.

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*Cited from Palczewska.

PLATE 1

EXPLANATION OF FIGURES

1 Illustration showing general character of humming birds' heart muscle. × 1500.

2 Illustration showing general character and distribution of the intercalated discs. The discs are more numerous and wider in a small area to the left which was evidently distorted by a longitudinal stress. One of the discs extends over two fibers. The discs are at the level of, and in numerous instances displace, the anisotropic bands. Many are seen to shade off on one or both sides into the anisotropic substance. × 1800.

3 Surface view of fiber showing relation of discs to anisotropic substance. × 1800.

4 Fibers in contracted condition. There is a gradual shading off from the two intercalated discs on the left through deeply staining wide anisotropic bands with narrow intervening isotropic bands, to areas having the usual appearance. × 1800.

5 Illustration showing the deeper staining character of the anisotropic bands, and the narrower width of the intervening isotropic bands, on either side of the central intercalated disc.

PLATE 2

6 Illustration showing the superficial intercalated disc lying over a central nucleus (shown only in outline). × 1800.

7 Illustration showing two intercalated discs side by side at upper end of fiber. In passing from a high to a slightly lower level of focus, the upper disc disappears as the lower enters the field, but without passing through a plate or line of disc-substance, as would occur if the discs represented portions of a cell boundary or cement substance. The plane of the longitudinal section is slightly oblique. × 1800.

8 Illustration showing sarcolemma-like membrane separated, probably mechanically, for some distance from the fiber. × 1800.

9 Fiber with three successive complete discs at same level of focus. × 1800.

10 Fiber with step-like intercalated disc, showing extensions of the 'steps' of the disc on either side beyond the 'risers,' a condition incompatible with a cement line. × 1800.

11 Two adjacent fibers with dot-like intercalated discs between. × 1800.

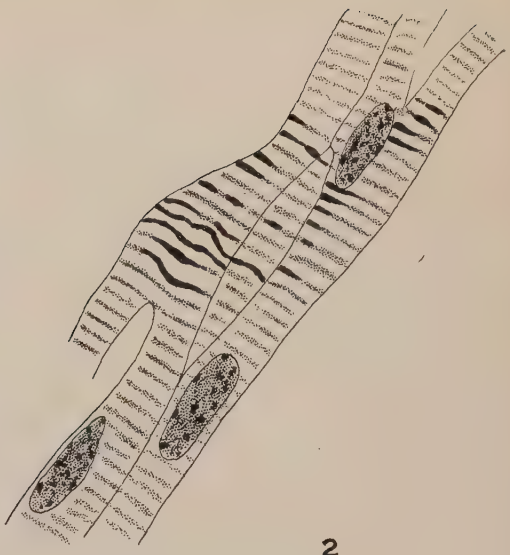
12 Fiber showing the individual fibrillae (after Fleming fixation, and iron haematoxylin stain). Certain of the anisotropic bands stain deeper and are somewhat wider. If the separate fibrillae were pressed closely together these would form plates, i.e., intercalated discs. In this preparation no discs, as such, can be found. × 1800.

13 Fiber on which appear seventeen dot-like superficial 'discs' continuous laterally with the anisotropic bands. × 1800.

14 Surface view of similar fiber with five dot-like 'discs.' × 1800.

15 Cross-sections of fibers showing the peripheral position of the intercalated discs, their slightly varying depth, their location sometimes over the nucleus; and the distribution of the fibrillae throughout the entire diameter of the fiber. × 1800.

1



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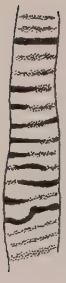

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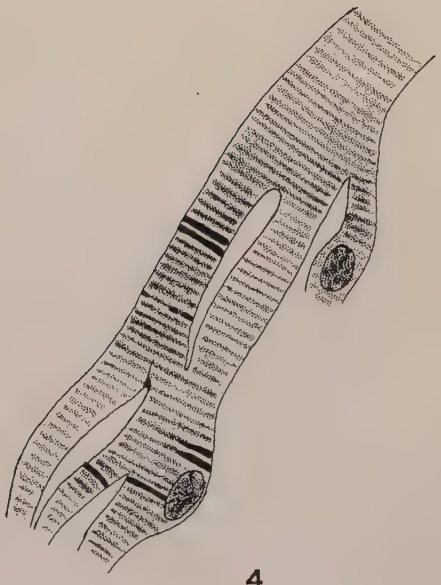

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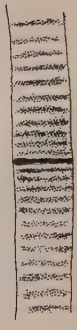

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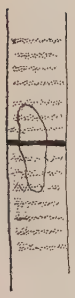

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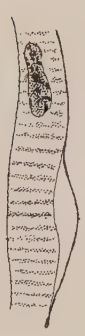

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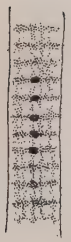

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15

THOMAS DWIGHT, M.D., LL.D.

Parkman Professor of Anatomy, Harvard Medical School

Harvard University suffered a great loss in the death of Professor Dwight which occurred at his summer home at Nahant, Massachusetts, on September 8, 1911, in the sixty-ninth year of his age. At the time of his death he had completed a career of nearly forty years as an investigator and teacher of anatomy, and during the last twenty-eight had held the Parkman Professorship, having succeeded the late Professor Oliver Wendell Holmes in 1883. For the last two years he suffered from an incurable disease, but far from being discouraged kept continuously at work in his department and gave practically all his regular lectures. His courage and cheerfulness never failed him during this distressing period and he was able to show in a way most satisfactory to himself and his colleagues what a man can accomplish in spite of physical suffering and an impending sentence of death. His abilities as a lecturer appeared to the best possible advantage during the term of 1910–11, in the last course he was to give, and at the same time he was able to add several valuable contributions to his work on osteology, that part of anatomical science which chiefly appealed to him, and in which he showed his best work as a scientist. Dr. Dwight's strong religious faith served him in good stead during this period of trial, but in addition to that source of comfort his own courage was above all praise, and enabled him to continue his work until the very end of his life.

Professor Dwight was born in Boston in 1843. As a very young boy he was taken abroad by his parents, making his first voyage in a sailing ship, and spent some years in Paris where he attended school. On his return home he completed his education in Boston and entered Harvard College with the class of 1866. He did not complete his college course, but left early and entering the Harvard Medical School obtained his degree of doctor of medicine in 1867. After leaving the Medical School he spent several years of study in Europe. He intended to engage in the active practice of his profession and attended the medical and surgical clinics of Berlin and Vienna, and also spent some time in England. There he had the opportunity of visiting Lister and hear-

ing from him personally the results of his investigations in antiseptic surgery. His chief interest, however, was anatomical science and natural history, and part of his time abroad was spent in that study under Rüdinger at Munich. There he obtained his first knowledge and experience of the use of frozen sections in anatomical work and was one of the first to introduce this method into America. In 1869 he returned to America and began practice in Boston and also in Nahant, his summer home. He continued in active practice for a number of years, but retired eventually in order to devote himself entirely to anatomy. During his active career as a practitioner he was surgeon to out-patients at the Boston City Hospital from 1877 to 1880, and visiting-surgeon at the Carney Hospital from 1876 to 1883. In 1883 he was appointed a member of the Board of Consultation of the Carney Hospital and acted as President of the staff until his resignation in 1898.

In 1872 he was made instructor in comparative anatomy at Harvard, and in 1874 instructor in histology and gave also some instruction in embryology. At this time he was offered the position of lecturer in anatomy at the Medical School of Maine at Bowdoin, and taught there until 1876, being Professor of Anatomy from 1873 to 1876. The course at Bowdoin began as a rule towards the end of February and consisted of about sixty lectures each term, chiefly on descriptive anatomy, but including some topographical anatomy. In 1880 he was made instructor in topographical anatomy at Harvard. In the autumn of 1882 Dr. Oliver Wendell Holmes resigned the Parkman Professorship of Anatomy, having served for thirty-five years. He was a brilliant lecturer with the ability of giving great interest to dry anatomical details by his powers of description and his wealth of comparison and simile. The anatomical lectures for the remainder of that term were given by Dr. Dwight and in 1883 he was appointed Parkman Professor of Anatomy.

Dr. Dwight was an excellent teacher and a strong, clear and forcible lecturer. Under him the course to first-year students was strengthened and expanded and a thorough course on regional and topographical anatomy for second-year men was gradually built up. He took especial interest in this advanced course and made it one of great practical value, but owing to changes in the curriculum this course had to be given up in 1903. This was a great disappointment to Dr. Dwight as he always considered the course to represent his best efforts in teaching. In the last few years he had developed a short course on X-ray anatomy which was intended to give the students some idea of the use of the X-ray and of the anatomical interpretations of X-ray plates. The course dealt

chiefly with the skeleton, but of late included some work in the head and body cavities.

Dr. Dwight's chief interest and his best anatomical work was in the anatomy of the skeleton and the joints, and on the normal variations in the body. His study of variations was applied chiefly to the spine and the hands and feet. For years he was engaged in making a very valuable collection of human spines showing practically all possible numerical variations of the ribs and of the vertebrae in different regions and of fusions between different parts. The results of these researches appeared in a memoir of the Boston Society of Natural History and in contributions to other anatomical journals. He also studied and described the abnormalities at the top of the spine which might cause malpositions of the head and face. After completing his studies on variations of the spine he devoted himself to the same subject in the hand and foot, and succeeded in obtaining a remarkable series of specimens showing the chief variations in the carpus and tarsus and including several unique cases of variations in these regions. He was the first to find and describe the subcapitatum as a separate and distinct element in both hands. This was especially satisfactory to him as Pfitzner had described the possibility of the separate existence of this element, but had never seen a case of it. In the foot he found two cases of an absolutely new element, the intercuneiform bone, which had never before been observed, and also two instances of the secondary cuboid bone. The first of these occurred in one foot and only one previous case had been seen by Schwalbe. The other occurred in both feet and was an unique case. In 1907 Dr. Dwight published an atlas on the variations of the bones of the hand and foot, based on the specimens in his collection and on X-rays. He was accustomed of late years to have X-rays made of all the hands and feet in the dissecting rooms and accumulated in this way a valuable collection of plates showing their normal structure and variations. He contributed the sections on bones and joints as well as those on the gastro-pulmonary system and accessory organs of nutrition in Piersol's anatomy. He made an extensive study extending over several years on the size of the articular surfaces of the long bones as a characteristic of sex, proving that the size of the articular ends were smaller in the female, and could be used as a means of identification. He was interested in the question of the estimation of height from the parts of the skeleton and on the identification of the human skeleton, and was able to make a practical use of his observations in several medico-legal cases. He wrote several articles on the general range and significance

of variations in the skeleton and also on the question of mutations. One of his earliest publications was an atlas of the frozen sections of a child, which were among the first frozen sections to be made in this country. He always laid great stress on the importance of such sections in anatomical study and made many series for the department and for the Museum. In addition to his work on the skeleton he wrote many other papers on anatomical subjects, a list of which will be found at the end of this paper. He wrote several other monographs on subjects not strictly anatomical. Among these were a biographical sketch of Sir Richard Owen, a reminiscence of Dr. Holmes as a professor of anatomy, papers on contortionists and right-handedness, and several others on the methods of instruction in the Harvard Medical School, its policy as to the increase in the number of professors and on changes in its medical curriculum.

Dr. Dwight devoted much of his time to the development of the anatomical part of the Warren Museum in the Medical School. It was his hope to be able to arrange the anatomical specimens so as to show the normal variations of all parts of the body. The osteological collection was completed in this manner and thanks to his efforts is very comprehensive and in many respects unique. He had done much to develop and arrange the other parts of the anatomical museum along the same lines, but was unable to complete them. His collection of corrosions and frozen sections was, however, very extensive and he had made much progress with variations of the large vessels, the kidneys and the joints. Under his supervision enlarged papier maché models of the skeleton and abdominal viscera were constructed which have proved of great value in teaching. He was very proud of the Museum and always impressed on his classes the practical value of a museum for the study and teaching of anatomy.

Dr. Dwight gave two courses of lectures at the Lowell Institute at Boston—one in 1884 on the mechanism of bone and muscle and another in 1889 on the significance of variations in the human body. From 1898 to 1908 he was a trustee of the Boston Public Library and gave freely of his time to aid in its development. He was much interested in that part of the library devoted to Catholic books and literature and the expansion of this department was due chiefly to his efforts. He was for many years a member of the Boston Society of Natural History and several of his papers appeared in the publications of this society. He did much work at one time in arranging and developing its osteological collections. He was president of the Association of American Anatom-

ists in 1894, and was also one of the original members of the editorial board of the American Journal of Anatomy and held this position until his death. From 1873 to 1878 he was an editor of the Boston Medical and Surgical Journal. Besides the Association of American Anatomists, he was a member of the American Society of Naturalists, Fellow of the American Academy of Arts and Sciences, a member of the St. Thomas Aquinas Academy of Philosophy and Medicine of Rome, an honorary member of the Anatomical Society of Great Britain and Ireland, a member of the American Medical Association, and a former member of the Massachusetts Medical Society and several other medical societies in Boston. In 1889 he received the degree of LL.D. from Georgetown University.

In addition to his work in the Medical School, Dr. Dwight took an active part in the affairs of the Catholic church of which he was a member, and was especially interested in the Society of St. Vincent de Paul. He joined the Holy Cross Conference in 1881, became its vice-president in 1884 and president in 1887. This position he resigned in 1892, but continued to remain a member. He was chosen president of the Central and Particular Councils of Boston in 1899 and held the former office until his death. He devoted much of his time to his religious work and to this society, and did much to further its welfare and influence. Dr. Dwight gave several addresses at meetings of the St. Vincent de Paul and other Catholic societies and conferences, notably one in 1908, before the American Federation of Catholic Societies at Boston on the relations of the Church and science. He completed a book entitled "Thoughts of a Catholic Anatomist" in the winter of 1911, and had the satisfaction of seeing it published before his death. This book contained his theories on evolution and his opinions on the relations between Catholic thought and science. His deep religious feeling and his devotion and loyalty to his faith were his strongest characteristics and influenced to a great degree his opinions and his scientific point of view.

The last two years of his life were passed under the handicap of an incurable disease, in spite of which he gave two full courses of lectures and added several monographs to his work on the skeleton. He had the good fortune to find the specimen of a free cuboides secundarium in one foot in the winter of 1910, and the unique specimen of that bone as a free element in both feet the following winter. The paper he wrote on the latter and another on irregular ossification in the transverse process and the rib at the junction of neck and thorax were his last contributions to anatomical science. He always looked forward to meeting

his classes at the first exercise in their medical career and although in the summer he knew he was failing, still hoped to meet this year's class at least once in the fall. This opportunity was denied him and his death occurred three weeks before the opening of the term. To all who had the privilege of being associated with Professor Dwight in the Department of Anatomy his courage in persisting in his work while suffering great discomfort and at times much pain was a most inspiring example. His ability and determination to show no sign of weakness enabled him to make the best possible use of the short time that was left to him. It gave him the satisfaction of continuing his work as a lecturer as well as his contributions to anatomical science to the very last, and was a worthy climax to his long and laborious career.

JOHN WARREN.

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This volume is an atlas of 40 cross sections through the brain of the rabbit, drawn on a large scale and provided with a very complete and accurate legend. On the figures are combined data from sections prepared by the methods of Weigert-Pal, carmine, Nissl and Van Gieson, and also from Marchi and von Gudden degeneration preparations. The work is designed primarily as a topographical guide for experimental operations on the rabbit's brain, but its field of usefulness will be much wider than this. As a point of departure for future researches on the comparative anatomy of the brains of the lower mammals, it will be invaluable. C. J. H.

THE TWENTY-EIGHTH SESSION OF THE AMERICAN ASSOCIATION OF ANATOMISTS

The twenty-eighth session of the American Association of Anatomists will be held at Princeton, New Jersey, under the auspices of Princeton University and in affiliation with the Society of American Naturalists and the American Society of Zoologists, during the last week in December and probably on December 27, 28 and 29, 1911.

Members of the American Association of Anatomists desiring to present papers or give demonstrations are requested to notify the Secretary on or before December 15. The attention of members with annual dues in arrears is called to the fact that the Association is under obligation to the publishers of The American Journal of Anatomy (vol. 11) and The Anatomical Record (vol. 5) for the numbers of these volumes issued during the past year and sent to the members. The Secretary-Treasurer is unable to meet these obligations until the annual dues for 1911 are paid in full.

G. Carl Huber, *Secretary-Treasurer,*
American Association of Anatomists,
1330 Hill Street,
Ann Arbor, Mich.

ON THE STROMA OF THE PROSTATE GLAND, WITH SPECIAL REFERENCE TO ITS CONNECTIVE TISSUE FIBERS

JEREMIAH S. FERGUSON

From Cornell University Medical College, New York City

FIVE FIGURES

The prostate gland consists essentially of secreting ducts and alveoli embedded in a stroma of connective tissue containing much smooth muscle. The smooth muscle is divisible into three portions: (1) the inner, which surrounds the urethra and consists of longitudinal and circular fibers; (2) the outer, which encapsulates the gland and is likewise disposed in longitudinal and circular bundles; and (3) that intermediate muscle which lies between the inner and outer divisions and whose fibers form interlacing bundles having a general trend from without inward.

Between the bundles of the intermediate muscle the glandular tissue is disposed in more or less slender conical lobules beginning with a broad base formed by dilated acini in the outer portion of the gland and tapering to an apex from which a duct leads inward to finally open on the surface of the prostatic urethra in the region of the colliculus seminalis.

The volume of smooth muscle in the framework or stroma is considerable; roughly, it forms nearly one-half of the tissue which is interposed between the glandular alveoli. Its fibers are coarse, and are easily observed in all preparations. They are specially distinct in sections which have been stained according to the iron-haematoxylin method of Heidenhain.

The muscle is embedded in a delicate network of connective tissue fibers which, unlike the usual arrangement, penetrate the muscle bundles and form between their individual fibers a close but delicate mesh.

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In sections prepared with the usual stains, e.g., haematoxylin and eosin, carmine, etc., it is difficult to distinguish the types of fibers composing the connective tissue mesh. When carefully observed, the connective tissue is seen to contain coarse, relatively straight fibers, and a much finer net of fibers of extreme delicacy but of very wavy contour. Specimens stained with the special stains for elastic tissue, e.g., orcein, or Weigert's resorcin-fuchsin, mixture, show a scanty network of elastic fibers within the connective tissue reticulum, but these form for the most part a very close mesh of fibers; they account for only a relatively small portion of the coarser fibers, and they lack the wavy contour of the bulk of the more delicate variety of connective tissue fibers. Altogether they form but an insignificant portion of the prostatic stroma.

It has hitherto been assumed that those fibers of the prostatic stroma which were not muscular nor elastic were to be classed as collaginous fibers, viz., 'white fibrous tissue.' Yet I find there are present two distinct types of fibers; (α) those which are extremely delicate and of decidedly wavy contour, and (β) those which are coarse and relatively straight.

With the connective tissue stain of Mallory both of the above types of connective tissue fibers take the light blue color and are indistinguishable in tint. With eosin both types are red. With iron-haematoxylin both take on a light golden brown tint of approximately equal intensity. With each of these stains the β-fibers are of slightly deeper tint than the α-fibers owing to their greater size and thickness. Their micro-chemical reactions are so far in each case those of ordinary collaginous fibers. But if one stains the prostatic stroma according to the 'newest' method of Bielschowsky,[1] the modification of Maresh[2] or of Levi,[3] the more delicate wavy fibers, with reasonable care in differentiation, always retain the golden brown tint characteristic of collaginous fibers, while the coarser, straighter fibers, if properly differentiated, assume an intense, opaque, black color identical

[1] Bielschowsky u. Pollack, Neurol. Centralbl., 1904, vol. 23, p. 387.
[2] Maresh, Centralbl. f. allg. Path. u. path. Anat., 1905, vol. 16. p. 641.
[3] Levi, Monitore zool. ital., 1907, vol. 18, p. 290.

with that which is acquired under similar conditions by the reticular fibers of lymphatic glands.[4]

I am not ready to assume that because of the similarity of color reaction after the silver impregnation of Bielschowsky these coarser fibers are identical with reticulum in the sense in which Mall[5] has used that term. In fact, there are distinct points of difference. Therefore it is better for the present to designate the coarse fibers as the β-collaginous, characterized by an opaque black reaction to the Bielschowsky stain, and to reserve the term α-collaginous for those characteristic, fine, wavy fibers which with the Bielschowsky stain assume a golden brown tint and which form the chief constituent of white fibrous and areolar tissues.

That the α and β fibers are closely related on grounds of physical chemistry is shown by the fact that with all other staining methods their color reactions are practically identical, and that even with the Bielschowsky method the characteristic difference is somewhat dependent on the care with which the sections are differentiated in the reducing and toning solutions. With this method, as with the very similar process of photographic printing, good pictures are obtainable only with extreme care in carrying out the minutest details of the process.

The α-collaginous fibers form a most delicate network which pervades all the interstices between the other tissues of the prostatic stroma. They are devoid of regular arrangement and appear to be promiscuously distributed among the other fibers. They are extremely fine.

They form an investing sheath about the β-fibers. The β-collaginous fibers, on the other hand, are disposed with considerable regularity, forming peculiar lines with curves or waves of considerable uniformity of degree and length, and so approximated as to enclose oval meshes the most numerous of which are about 10μ in diameter, many are larger. They differ from typical reticulum in that they are accompanied by few 'fixed' cells so that nuclei do not occur at the intersections of fibers. These fibers are found in all parts of the prostate gland; they are, perhaps, relatively

[4] Ferguson, Anat. Record, 1911, vol. 5, p. 249.

[5] Mall, Bull. J. H. Hosp., 1896, vol. 1, p. 171.

more abundant in the narrow septa between the lobular acini. In this location the meshes are frequently occupied by the capillary vessels which occur with great frequency close beneath the glandular epithelium (fig. 2).

It is usually stated that the acini of the prostate have no membrana propria or basement membrane. Kölliker[6] states that beneath the prostatic epithelium a membrana propria is entirely wanting. Oppel[7] says that careful examination with the best immersion systems failed to reveal any structure in the layer beneath the epithelium. Sections of the prostate prepared with the Bielschowsky method show beneath the glandular epithelium of nearly all of the acini a very definite membranous layer, consisting of closely interlaced β-collaginous fibers, upon which the epithelium directly rests (fig. 3, *b.m.*). On examining such sections, even with very low magnification (e.g., $\times$ 60) one is immediately impressed with the prominence of the membrane. In haematoxylin-eosin sections this membrana propria, for such we may call it, can scarcely be recognized; with iron-haematoxylin it can scarcely be discerned and is not sharply differentiated; with the Mallory connective tissue stain it can be distinguished but lacks prominence because of the absence of color differentiation from the α-collaginous fibers.

The fibers of the β-collaginous membrane of the mucosa are continuous with the similar fibers which form the coarser network of 'white fibers' between the walls of the glandular acini, and whose meshes form the peculiar oval areas already described, such areas as are characteristic of the β-collaginous fibers wherever found, and to which attention has already been drawn by Ciaccio[8] in his description of the 'perifollicular plexus' about the nodules of lymphoid organs. This peculiar conformation appears to be due to a tendency of these fibers to pursue a spiral course. I have observed this tendency not only in the prostate and in lymphatic organs, but elsewhere, e.g., among the collaginous fibers of the derma, and among the fibers of elastic tissue (liga-

[6] Kölliker Gewebelehre, 6te Aufl., Bd. 3, S. 470.
[7] Oppel, Lehrb. d. vergleich. mik. Anat., Teil 4, S. 397.
[8] Ciaccio, Anat. Anz., 1907, vol. 31, p. 594.

mentum nuchae, arterial tunica intima, etc.); in this last location their spiral character is most apparent (fig. 4).

The β-collaginous fibers closely invest the blood-vessels, the capillaries as well as the adventitia of the arterioles and venules. Oppel[9] has shown an excellent figure of the relation of these fibers to the capillary vessels but without directing attention to their peculiar character. The capillaries are enclosed within the oval meshes formed by these peculiar fibers. The endothelium rests directly upon the fibers.

The disposition of the β-collaginous fibers within the muscular tissue of the prostate is also peculiar and characteristic. The larger bundles of smooth muscle are not always penetrated throughout, but in the smaller bundles the β-fibers form delicate, rounded oval meshes, whose fibers are intricately interlaced, and within the spaces of which are the individual muscle cells. Even if a smooth muscle fiber lies isolated within the prostatic stroma it will usually be found surrounded by the interlacing β-fibers by which it will be inclosed within an oval space (fig. 5). The muscle fibers are not, however, over closely grasped by the enveloping β-fibers, there being usually a narrow interval between muscle and collaginous fiber.

SUMMARY

The method of Bielschowsky discloses within the prostatic stroma, in addition to smooth muscle and elastic fibers, *two types of collaginous fibers*, the one being of the wavy variety usually designated as typical 'white fibers' though here they are of rather unusual delicacy, and the second a type which we have called the β-collaginous and which in successful Bielschowsky preparations are characterized by an opaque black color reaction; these last form a membrana propria supporting the glandular epithelium, and an interlacing network throughout the interglandular tissue. They closely invest the blood vessels and penetrate between the individual fibers of the smooth muscle bundles. That they are not elastic fibers is amply demonstrated by the

[9] Oppel, loc. cit.

fact that they do not react to the special stains for elastic tissue, and by the additional fact that elastic fibers in known locations, e.g., in the tunica intima of the arteries, or in the ligamentum nuchae, remain colorless when treated in accordance with the Bielschowsky method.[10]

The above study was partially conducted on sections which had been prepared under my direction by Mr. I. Rosen, first year student in the Cornell University Medical College, for whose assistance I am greatly indebted.

PLATE 1

EXPLANATION OF FIGURES

1 α-and β-collaginous fibers from the stroma of the human prostate gland. The β-fibers are coarse and black, the α-fibers much finer and of a golden brown color in the original preparation. Bielschowsky stain. Drawn with Edinger projection apparatus, $\times$ 900, reduced one-fourth in reproduction.

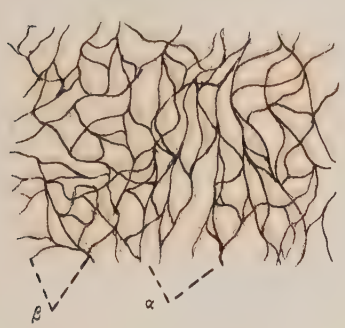
2 The epithelium and intervening stroma of adjacent prostatic alveoli. β, β-collaginous fibers; *bl. ves.*, blood-vessels; *ep.*, secretory epithelium of the prostate. Bielschowsky stain. Drawn with Edinger projection apparatus, $\times$ 270, reduced one-fourth in reproduction.

3 Several alveoli and the intervening stroma of the prostate gland. The basement membrane is prominent, even with relatively low magnification. *b.m.*, basement membrane *ep*, epithelium of the prostatic alveoli. Bielschowsky stain. Drawn with Edinger projection apparatus, $\times$ 200, reduced one-third in reproduction.

4 Isolated β-collaginous fibers from the tunica intima of the human aorta, showing their typically spiral course. Bielschowsky stain. Drawn with Edinger projection apparatus, $\times$ 270, reduced one-fourth in reproduction.

5 The β-collaginous fibers of a muscle bundle of the prostatic stroma. At the right of the fibers the smooth muscle fibers were transversely, at the left of the figure they were longitudinally cut. The muscle fibers are not represented; each mesh at the right of the figure enclosed a single muscle fiber, and a single muscle fiber occupied each interstice between adjacent β-collaginous fibers at the left. α-collaginous fibers, indicated by the finer and lighter lines are found between muscle bundles and about the coarser β-fibers. *L.S.*, portion longitudinally cut; *T.S.*, portion transversely cut. Bielschowsky stain. Drawn with Edinger projection apparatus, $\times$ 270, reduced one-fourth in reproduction.

[10] Ferguson, Am. Jour. Anat., vol. 12, no. 3, 1911.



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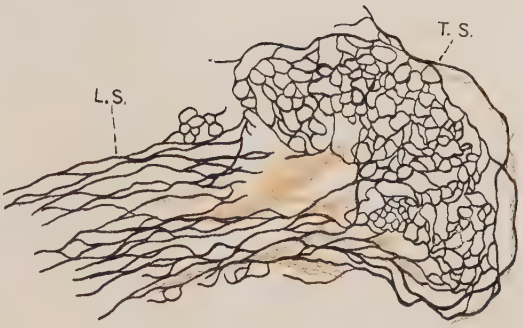

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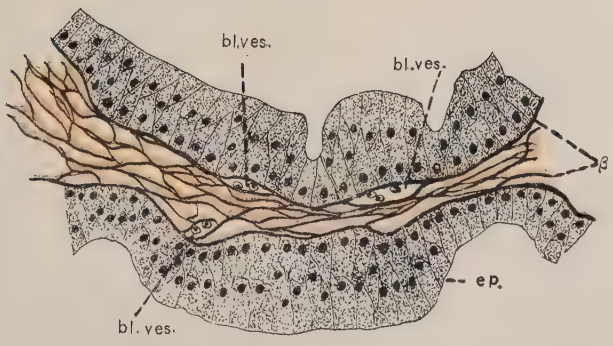

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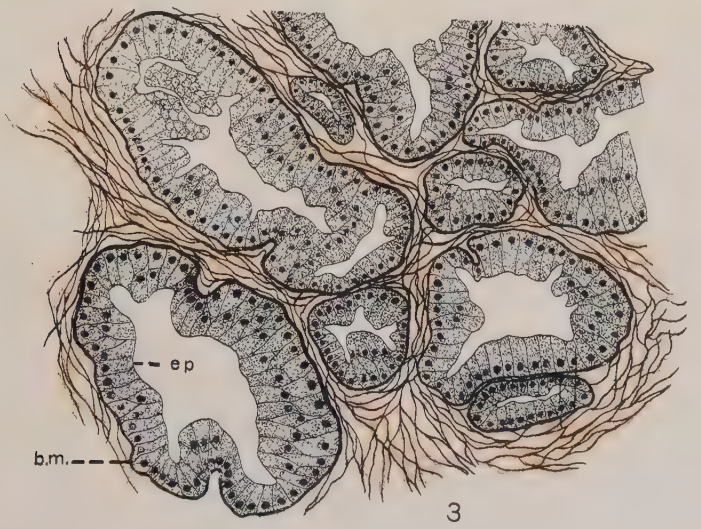

3

A STATISTICAL REVIEW OF THE VARIATIONS IN THE ANATOMIC POSITIONS OF THE CAECUM AND THE PROCESSUS VERMIFORMIS IN THE INFANT

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The following statistical review of the common variations in the position of the caecum and the appendix in the infant, is based on observations made in a series of 1050 autopsies of infants performed at the New York Foundling Hospital. This paper discusses briefly, in addition, some of the variations of the folds and the fossae occurring in the ileo-caecal and duodeno-jejunal region in the infant, and some observations made on the variations of the mesenteries of the large intestine. The infants examined were for the most part under three months old, although a moderate number exceeded that age. In all cases, the ileo-caecal region of the abdomen was exposed by an incision through the right rectus muscle; the thoracic cavity was opened only after the abdominal examination.

The gradual changes, resulting in the withdrawal of the intestine into the abdominal cavity and the shifting in position of the ileo-cecal part of the intestine so as to reach the region below the liver at about the third month, are processes occurring at an earlier period of development and need not be described here. The final descent of the caecum to the right iliac fossa takes place, according to Hertwig (1) and also Keith (2), in the eight month of intra-uterine life. An arrest in process of rotation of the intestine on the axis of the superior mesenteric artery may occur at any stage, resulting in fixation of the caecum in positions varying over a wide range from the normal. In table 1, a summary is made of such variations in the position of the caecum as were observed in the material examined.

TABLE 1

Caecum on left side of abdomen with failure of rotation of the intestine.	Male..... 2 Female..... 3 —	5
Caecum undescended lying between the under surface of liver and right iliac crest.	Male..... 31 Female..... 32 —	63
Caecum in the right iliac fossa.	Male..... 443 Female..... 439 —	882
Caecum in the pelvis.....	Male..... 34 Female..... 66 —	100
		1,050

In five instances, the caecum and the vermiform process were found in the left side of the abdomen; in three of these, the caecum occupied a position in the left iliac fossa close to the iliac crest, and in two the caecum was found near the left side of the pelvic brim. These cases presented a complete failure of rotation of the intestine. The ileum entered the large intestine from the right side. The descending colon was definitely fixed in the usual position, either with or without a mesentery. The transverse colon and ascending colon were irregularly folded, lying in the middle and left regions of the abdomen. The great omentum was distributed over the surface of these loops of the large intestine, in some places binding two adjacent coils closely together. The coils of the small intestine were found occupying chiefly the right side of the abdomen. The duodenum varied considerably in the fixation of its upper portion to the posterior parietes, being movable in all save one case in which the fusion with the posterior parietes was more extensive.

With the caecum in an incompletely descended position, it was not infrequently found in contact with the under surface of the liver. In such cases, the appendix also was occasionally found touching the liver. In the majority of cases of incomplete descent, the caecum rested near the iliac crest, at times

firmly fixed to the posterior parietes. In many cases, the subsequent development of the caecal pouch would have brought the caecum into a closer relation with the iliac fossa.

When in the iliac fossa, the caecum commonly occupied a deep position near the posterior part of the iliac crest. Less often, the caecum was found placed nearer the anterior abdominal wall, associated often with an appendix which passed over the psoas muscle into the pelvic cavity. The anterior position of the caecum suggested a moderate hyper-descent, a condition which finds its expression best with the caecum lying entirely in the pelvis. Accidental displacement of the caecum, chiefly due to distention of the ascending colon with gas was met with at times but these cases could be readily classified in nearly all instances.

The cases in the above table, grouped as caecum found in the pelvis, include all those in which the caecum was located below the pelvic brim. The condition was present twice as frequently in the female as in the male. In nineteen cases the caecum was found to lie directly on the pelvic floor in close relation with the posterior surface of the bladder and usually to the right and in front of the rectum.

The classification adopted by Huntington (3), in discussing variations in the position of the vermiform process in the adult, is applied here in grouping the variations of the infant. The results in the 882 cases, in which the caecum was in the iliac fossa are classified in table 2.

As pointed out by Huntington, the conical shaped caecum of the infant, with its rapidly developing right sacculation forming a crescentic border extending from right to left, gives to the proximal part of the appendix a definite direction to the left and upward causing it to lie near the terminal coil of the ileum (table 2, type I). Similarly in this series, it was noted that when the caecum was directed dorsally, the appendix usually assumed a posterior position in close relation to the caecum and the ascending colon (table 2, type II).

In both type I and II, the appendix was found frequently influenced by the limits of the retro-colic space. This space, bounded medially by the prominent psoas muscle and the fold of peri-

TABLE 2

Type I. Appendix in the iliac fossa, proximal part passing upward, and to the left, the distal part lying behind terminal coil of the ileum.	Male.....232 Female.....217	449
Type II. Appendix in the iliac fossa, passing directly behind the caecum and proximal part of the ascending colon and in close relation to these.	Male.....110 Female.....104	214
Type III. Proximal part of the appendix in the iliac fossa passing upward and to the left, the distal part downward over the pelvic brim so as to lie in the pelvis.	Male..... 84 Female..... 84	168
Type IV. Appendix hanging vertically downward from the caecum.	Male..... 19 Female..... 7	26
Type V. Aberrant positions of the appendix (all not found in types I and IV).	Male.....15 Female..... 10	25
		882

toneum continuous with the attachment of the lower part of the common mesentery, and above by the reflection of the peritoneum from the proximal part of the ascending colon to the posterior parietes of the iliac fossa, appeared at birth to be relatively small. The appendix, relatively large at birth and during early infancy, in accommodating itself to the limits of this space, not infrequently was found to have some deflection, sharp angulation or even spiral twist in its long axis. Sharp angulation was especially common in type II, when the appendix, lying in close contact with the caecum and colon met abruptly the upper limit of the retro-colic compartment. In the retro-colic type of appendix (type II) fusion of the appendix with either the caecum, the colon, posterior parietes or iliac fossa was often present even in the new-born, and angulations of the appendix formed under such conditions doubtless would have been of permanent character. In older infants

when the retro-colic space has grown in its dimensions, the appendix at times was found with its angulation lying within but at some distance from the limits of the retro-colic compartment, still preserving angulations with the characters seen so frequently at the time of birth when the appendix is in close contact with these same boundaries. Where fusion of the appendix with adjacent peritoneum had occurred, the mesentery of the appendix often apparently shared in this process, resulting in changes in its form.[1]

In cases where the proximal part of the appendix was found crossing over the pelvic brim with the distal part lying in the pelvis, (type III) the caecum was, as mentioned above, usually lying well anterior and close to the anterior abdominal wall.

In type IV the appendix hung vertically downward and had its origin from a vertically placed caecum in which the right and the left sacculations were equally well developed. There was no indication of the sharp crescentic right margin of the caecum seen under usual conditions when the right side of the caput begins to grow relatively faster than the left. The distal part of the appendix in this class was found to have entered the pelvis in seventeen out of a total of twenty-six cases.

Under type V are grouped all unusual positions of appendix not classified in types I to IV. Chief among these were appendices which had assumed a position anterior to the ileo-caecal junction, and also those appendices which, crossing in front of the caecum, subsequently assumed a position along the outer margin of the ascending colon.

In subjects where the caecum was found in the pelvis, the appendix generally bore one of two relations to the caecum. With the caecum horizontal and its crescentic margin directed from right to left, the proximal part of the appendix passed upward and to left; the distal part usually curved again downward. With the caecum directed backward, the proximal part of the appendix was erect and in close relation with the posterior part of the caecum and the first part of the ascending colon; the distal part of

[1] The pathological significance of some of the anatomic positions of the appendix has been discussed by me in another paper (4).

the appendix either arose above the pelvic brim, or became deflected downward and remained intra-pelvic. The frequent occurrence of the ascending colon attached to the inner margin of the psoas near the pelvic brim, argued for a permanent position of the caecum and appendix in the pelvis, determined even at the time of birth.

In five cases in the 1050 examined, the mesentery of the appendix was formed by the anterior vascular ileo-colic fold, instead of the posterior vascular ileo-colic fold. The main blood supply to the appendix occurred apparently through the anterior branch of the ileo-colic artery present in the anterior fold. A fusion with the middle non-vascular fold was noted in each of the cases forming a deep well-developed fossa.

A study was made in 982 cases of the arrangement of the mesentery of the ascending and the descending colon. The extent of the ascending mesocolon was not always readily defined because of the obliquity of the course of the colon when associated with a

TABLE 3

1. Cases with ascending and descending mesocolons.	Male..... 95 Female.....103	——	198
2. Cases without ascending and descending mesocolons.	Male.....250 Female.....247	——	497
3. Cases with ascending but without descending mesocolons.	Male..... 51 Female..... 53	——	104
4. Cases without ascending but with descending mesocolons.	Male..... 87 Female..... 79	——	166
5. Cases with free primary ascending mesocolons.	Male..... 7 Female..... 10	——	17
			982

large liver in the new-born. Thus, in some cases in which the ascending colon was firmly fixed in the lower and first part without a mesentery, it possessed considerable mesentery higher up when about to cross in front of duodenum. The descending colon beginning at the sharp splenic flexure, offered no difficulty in such a study. The results are briefly summarized in table 3.

In seventeen cases grouped as primary mesocolon there had been no attempt at fusion of the mesentery of the ascending colon with the peritoneum of the posterior parietes, a condition found occasionally persistent in the adult. The ascending colon hung free with its large original mesentery continuous with that of the small intestine. As a result of this extreme mobility of the ascending colon, the caecum and parts of the ascending colon were found prolapsed in the pelvis in three instances.

In 750 subjects, arrangement of the folds and fossae in the region of the duodeno-jejunal region was noted. These results are tabulated as follows (table 4):

TABLE 4

(*a*) Superior duodeno-jejunal fossa present alone.	Male	37	
	Female	49	
		—	86
(*b*) Inferior duodeno-jejunal fossa present alone.	Male	84	
	Female	59	
		—	143
(*c*) Superior and inferior fossa present at same time without fusion of left margin.	Male	45	
	Female	65	
		—	110
(*d*) Superior and inferior present at same time with fusion of left margin.	Male	46	
	Female	50	
		—	96
(*e*) Absence of folds and fossae.	Male	161	
	Female	154	
		—	315
			750

The duodeno-jejunal folds and fossae when present in the infant are sharply and clearly defined. Intermediary folds often described in the adult, are frequently found in the infant, but less clearly defined and often artificially created by producing too much tension on the parts when the region is examined. The inferior mesenteric vein was found lying in the free margin of the inferior duodenal fold in 114 cases, the fossa corresponding under such condition to that usually described as the fossa of Treitz. Large folds formed by peritoneum raised by the left colic artery or its branches were met with occasionally. In one instance, a large hernial sac had been formed by a fossa produced in this way, and contained about 30 cm. of small intestine.

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1 Hertwig, O. 1902 Lehrbuch der Entwicklungsgeschichte des Menschen und der Wirbelthiere. Jena, p. 349.

2 Keith, Arthur 1910 Human embryology and morphology. London, p. 344.

3 Huntington, George H. 1903 The anatomy of the peritoneum and abdominal cavity. Pp. 250–251.

4 Smith, George M. 1911 Amer. Jour. Children's Diseases, April, vol. 1, no. 4, p. 299.

THE LARYNGEAL CARTILAGES OF AMBYSTOMA

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FOUR FIGURES

Probably the greatest interest in a consideration of the laryngeal region in Amphibia is in connection with the general homology and development of the respiratory cartilages of Vertebrates. Wilder and Gegenbaur in 1892,[1] independently of each other, made the suggestion that the cartilages of the larynx and trachea, as a whole or in part, were homologous with the fifth brachial arch. This was first suggested to Wilder by the fact that every form possesses either a pair of laryngeal cartilages, or a pair of fifth brachial arches, but no animal possesses both. It was first suggested to Gegenbaur by the musculature of the larynx which was found to be essentially branchial. Drüner[2], who worked on the anatomy of this region in a number of Urodela, held much the same view.

Henle, in 1839[3], first recognized two cartilages, one on either side of the larynx which he called 'lateral cartilages,' and he considered them to be primitive and to represent those of the larynx and trachea. Wilder was of the opinion that these cartilages about the upper larynx corresponded to the fifth arch, the 'lateral cartilages' representing the artenoids of higher forms, while he considered the other tracheal elements to be a new formation arising directly from connective tissue. Upon further investigation,[4] Wilder abandoned his idea of an independent origin of the tracheal elements and reverted to that of Henle as accepted by Gegenbaur. Drüner is more inclined to Wilder's first view.

[1] Wilder, H. H.: Studies on the phylogenesis of the larynx. Anat. Anz., Bd. 5, 1892. Gegenbaur, C.: Vergl. Anat. Studie, Leipzig, 1892.

[2] Zool. Jarb., Bd. 15, 1901, and Bd. 19, 1904.

[3] Vergl. Anat. Beschreibung des Kehlkopfes, Leipzig, 1839.

[4] Zool. Jahrb. abt. f. Anat. u. ontog. Bd. 60, 1896.

In Salamandra and Siredon, he says that the first cartilages of the larynx and trachea are isolated cell groups, these later become fused into a single piece on each side although each may divide again into several parts. He believes that the single lateral cartilage of Proteus and Necturus, which Gegenbaur considers as primitive, is a secondary formation.

Through the kindness of Profs. Gage, Kingsbury and Reed, I have been able to examine an unusually large and complete series of Amphibian preparations consisting of numerous species of old and new world forms. Ambystoma punctatum was selected for study and over a hundred series through the heads of embryos, larvae and adults were examined. In this species the tracheal cartilages seem to be of the same origin as those of the larynx, because the early mesenchymal cells which go to form them are continuous with those that form the laryngeal cartilages. Fig. 1 shows a camera lucida sketch of a longitudinal section through the larynx and trachea at an early stage when the cells from the two regions are continuous. In later development certain centers where there is a rapid growth of precartilage cells come to be partly isolated from each other. Possibly in other species this condition may be carried along to the adult condition, but in Ambystoma this segmental character is only partial and is succeeded by a stage where the laryngeal and tracheal cartilages are practically one piece. Fig. 2 is a longitudinal section of the larynx of $21\frac{1}{2}$ mm. larva and at the plane of section given shows only the upper part of the cartilage a little darker than the rest. Fig. 3 shows a longitudinal section from a full grown larva where the cartilage is uniform throughout. In later stages the pulmonary ends of these cartilages may have little bits partially isolated from the main bars.

A summary of these various stages of development in Ambystoma is as follows:

1. Mesenchymal cells either sides of the larynx and trachea.
2. The extension of the cells down along the cavity of the larynx and trachea, until there is a rather uniform mass of precartilage cells down to the beginnings of the lungs.
3. Growth in length of the tracheo-laryngeal tube with a corresponding growth in the precartilage cells on the sides.

1

2

Fig. 1 Longitudinal section of the larynx of an embryo Ambystoma of 11.5 mm. length, showing the two masses of early precartilage on either side of the larynx and trachea. × 50.

Fig. 2 Longitudinal section through the central part of the larynx, trachea and lungs of a 21½ mm. larva. In this section the lateral pouches show and the laryngeal and tracheal cartilages are a more or less uniform mass. This is not true for sections one side of the middle line and even in this there is some distinction between laryngeal and tracheal cartilages. × 50.

4. Development of decided centers of growth in the mass of cartilage, one center for each side of the larynx and several for each side of the trachea.

5. Later fusion of all the centers into one uniform cartilage either side of the trachea and larynx, at about the time of transformation and the growth of the so-called tracheal 'processes.'

6. Finally a partial or complete isolation of bits of the lateral cartilages at their caudal extremities, in the larval or adult.

If the laryngeal cartilages represent fifth branchial arches, then we ought to expect to find additional gill pouches between them and the fourth. Undoubtedly the pits recognized by Kingsley[5] in the head of an embryo Amphiuma were of this nature and correctly interpreted by him. In Ambystoma, these pits were easily recognized in all stages of embryos and very young larvae and remained as constant features until they like other gill pouches disappeared at transformation. In other species examined, these pits were not clearly recognized, partly because the series of stages for other genera were not so complete, but probably also because their occurrence is not constant.

The development of the little pocket or extra gill pouch between the fourth gill arch and laryngeal cartilage begins as a minute cleft in the epithelium, a sort of separation between some of the surface cells, with little or no change in the connective tissue. Later, these little depressions are found in the connective tissue as well. Fig. 4 shows a cross section through the laryngeal region of a larva with little pockets each side of the laryngeal opening into the esophagus. Fig. 2 shows the pits either side of the laryngeal opening in an earlier stage, and fig. 3 shows them in a full grown larva. In all but one of the specimens, the larynx from the earliest stage is an open tube, but in this one there was some indication of the solid condition such as has been found in some Anura.[6]

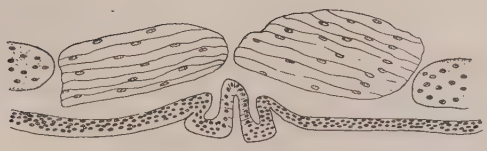
From the history of the cells which form the laryngeal and tracheal cartilages of Ambystoma, it seems clear that they both

[5] Am. Nat., vol. 26, 1892.

[6] Gage, S. H. and Hemstead, M.: Science, vol. 12, 1900.

have the same origin and because of the extra gill pouch between them and the fourth arches there seems to be some additional confirmation to the theory that they represent a fifth gill arch.

3



4

Fig. 3 Longitudinal section through the larynx and trachea of a full grown larva just before transformation showing the laryngeal and tracheal cartilages as a single rod on each of the lumen. Sections one side of this show partially isolated bits of cartilage near the lungs. The pit either side of the larynx is well marked. × 15.

Fig. 4 Cross section through the cephalic part of a full grown larva showing a pit each side of the larynx. × 15.

BOOK REVIEW

THE MICROSCOPE. Simon Henry Gage. Comstock Publishing Company, Ithaca, New York.

The eleventh edition of The Microscope by Simon Henry Gage, Professor of Histology and Embryology, Emeritus, in Cornell University, revised and illustrated by over two hundred figures, has just been issued by the Comstock Publishing Company, Ithaca, N. Y.

In his preface to this edition Professor Gage states that except for the correction of a few typographical errors, and except for a few additions which it seemed unwise to keep waiting until the complete revision and reprinting of the entire work at some time in the future, this edition is practically unchanged from the tenth edition, published in 1908.

The book is so well known that a lengthy review is unnecessary. In it is found, as implied in the title, a scientific consideration of the microscope and its accessories, a thorough understanding of which is so desirable for their proper use.

The microscope, as an optical apparatus, is first considered with reference to the physical principles on which it is constructed. Then follows a definition of terms, instructions for manipulation and care of the microscope and an interpretation of appearances under it. Further chapters consider magnification and micrometry, drawing with the microscope, camera lucida and projection apparatus. The micro-spectroscope, micro-polariscope, the preparation of slides for micro-chemistry, the microscope in metallography, the apertometer, and determination of equivalent foci are discussed with Professor Gage's usual clearness of expression.

An entire chapter is given to photo-micrography. Constant references are made to original sources in books and periodicals so that the investigator, the teacher and the ambitious student may find fuller treatment of any subject in which he is especially interested.

Among the additions, Professor Gage presents a discussion and illustration of a new condenser for dark ground ilumination, and a double demonstration ocular with pointer, designed and perfected in the Leitz works at the request of Edinger. This ocular is particularly valuable sa it enables two people to observe the same field at the same time, and bv means of the pointer the one is able to indicate to the other the exact part of the field under consideration.

In addition to the microscope and its accessories, the book contains illustrations of many valuable pieces of apparatus and laboratory equipment which Professor Gage worked out for his laboratory.

Among the latter, the slide trays, fig. 213; the student lockers, fig. 214; and the washing apparatus, fig. 226, are particularly meritorious.

Those who work with the microscope are much indebted to Professor Gage for the concise information and useful suggestions found in this book.

B. D. M.

NOTE ON M. W. BLACKMAN'S ARTICLE "THE ANAL GLANDS OF MEPHITIS MEPHITICA," IN THE ANATOMICAL RECORD FOR NOVEMBER 20, 1911

LEWELLYS F. BARKER

Mr. M. W. Blackman states that the only reference he has been able to find with regard to the anal glands of Mephitis mephitica and of similar animals is a very brief account accompanied by a figure by Dalgren and Kepner, 1908.

It is perhaps not surprising that he should have overlooked my study of these glands, inasmuch as it was not published in an anatomical journal, but as a note included in the article by T. B. Aldrich, entitled "A Chemical Study of the Secretion of the Anal Glands of Mephitis mephitica (Common Skunk), with Remarks on the Physiological Properties of this Secretion," in the Journal of Experimental Medicine, 1896, No. 2.

It is gratifying to me to find that Mr. Blackman, in his careful study of the glands, comes to conclusions similar to those reached by myself. In my histological report I laid especial emphasis upon the resemblance of the structure of the glands in the wall of the reservoir to that of the ordinary sudoriferous glands of the skin, and suggested that these glands of the skunk may represent curiously modified sweat glands. For the detailed histological report, the Journal of Experimental Medicine may be consulted.

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